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Planner's Primer on Extreme Heat Events and Hazard Mitigation Planning

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Planner's Primer on Extreme Heat Events and Hazard Mitigation Planning

by

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Abstract

Planner's Primer on Extreme Heat Events and Hazard Mitigation Planning

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The amount of information available on individual hazards can appear overwhelming to a planning organization managing multiple, large-scale projects. While hazard mitigation planning is required by federal law, it is often an elective topic in university planning programs. This paper is intended to serve as an introduction to a specific hazard: extreme heat events. It is important for planners to understand this topic because nearly all United States municipalities face the threat of more frequent, more intense, and longer duration extreme heat events, largely due to human-induced climate change. To draft this paper, I carried out my work in two phases. First, I conducted a literature review to answer the question, "What information about extreme heat events is relevant to planning professionals?" Second, I used the City of Baltimore, Maryland, as a case study for applying this knowledge to identify how their extreme heat event hazard planning documents might be strengthened by the knowledge accumulated in the first phase.

My primary findings from the literature review highlight the importance of establishing a definition for extreme heat events, understanding the history of extreme heat events, realizing the amplifying effect of climate change and the urban heat island effect on extreme heat events, and the importance of understanding and identifying socially vulnerable populations and communities.

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Executive Summary

Extreme heat events are the deadliest natural hazards in the United States by record of the National Weather Service since the agency added extreme heat event related fatalities to their list of tracked natural hazards. Over the past 30 years, 130 deaths per year on average have been attributed to extreme heat events in the United States, a likely undercounted attribution rate. To help put this count into perspective, hurricanes have killed an average of 30 people per year in the United States in the same time frame. Extreme heat events receive less attention in local hazard mitigation planning documents, possibly due to the lack of high impact imagery and lower values of measurable economic damage. However, researchers in government and academia have published a large volume of papers and books highlighting the dangers posed by extreme heat events. This professional report condenses these works into a series of key points that all planners should know regarding extreme heat events. To protect our communities from extreme heat events, planners should understand that:

- Although FEMA requires all communities to receive approval of multi-hazard mitigation plans to receive federal hazard mitigation funding, the relevant law (Disaster Mitigation Act of 2000) and federal rule (44 CFR §201.6) do not require adherence to best practices. Neither the law nor rule requires communities to address climate change or social vulnerability in their hazard planning documents. In alignment with the purpose of multi-hazard mitigation plans but contrary to the U.S. government's position stated through the relevant laws, independent research demonstrates that these two issues are important for identifying and mitigating the risks posed by extreme heat events.

- Developing a universal definition for extreme heat events has proven to be a problematic undertaking for researchers. Due to humans' biological ability to acclimatize to heat, people experience negative health effects from extreme heat at different heat index values. This differential can be attributed to the historical temperatures of a location, the building stock, demographic characteristics, and social inequities. Because of the issues in establishing a universal definition, planners should develop a local definition for declaring extreme heat events. It is important to consider local mean average temperatures, maximum heat index values, and duration of consecutive extremely hot days and nights. Public health research has shown an increase in heat-related fatalities with temperatures in the 85th percentile of a community's heat index.
- Past extreme heat events highlight weaknesses in government and community response to extreme heat events. The Chicago Heat Wave of 1995 highlighted weaknesses in:
    - communication between emergency response services and healthcare providers
    - the effectiveness of the government and media to communicate the threat posed by an extreme heat event and available resources
    - planning for providing unusual levels of government services to prevent overstressing of emergency and social services

  Planners should conduct a historical review of local extreme heat events to identify past weaknesses in communication, outreach, emergency response, and other areas.
- Climate change is increasing the duration, frequency, and intensity of extreme heat events in nearly every community in the United States. This increase in individual events is paired with a general increase of average daily temperatures. Our future under climate change means that failing to plan now will result in unnecessary human suffering.

- Urban communities face a greater threat due to the design of the built environment. The urban heat island effect is the measured increase in the daytime and nighttime temperatures of urban areas in comparison to the surrounding suburban and rural areas. Decisions made regarding building and development codes have intensified the daytime retention and nighttime release of heat in urbanized areas. Future decisions can reduce increased urban temperatures through decisions that emphasize energy efficient designs of buildings and infrastructure combined with afforestation of the urban environment.
- Extreme heat, like other hazards, does not affect all people equally. Social vulnerability refers to a community's ability—or more importantly, inability—to resist and recover from the risks posed by hazard events. Since the introduction of social vulnerability in the emergency management literature in the early 1990s, researchers have expanded the research to include ways of measuring social vulnerability to identify and locate at-risk populations. While the most common social vulnerability indices measure social vulnerability to hazards in general, there has been work to develop hazard-specific vulnerability indices. Regularly updated maps of general social vulnerability at the Census tract level are readily available from the Centers for Disease Control and Prevention. Communities can use geospatial information systems to create maps identifying hazard-specific social vulnerability.

This professional report can serve a planner preparing to write, or rewrite, a community's hazard mitigation plans. As an example, I conclude this paper by applying the knowledge presented in this professional report to an analysis of the City of Baltimore's extreme heat event-related planning documents.

Chapter 1 - Introduction

Overview

Growing up in central Florida and living in central Texas, extreme heat has been an important variable throughout my life. Extreme heat will soon be a global problem. Although, arguably, it is a global problem already. Extreme heat events are predicted to increase in frequency and intensity for a majority of the populated globe, including almost all regions of the United States. Overconsumption of resources by humans and general inaction to modify or reverse polluting practices are primary causes of climate change that are leading to increases in the frequency, duration, and intensity of extreme heat events. There will be dangerous quality of life effects as a result of our inaction, especially upon the people least able to cope with our current predicament and least able to handle the damage and stress of the impending disasters.

While I knew that I wanted to discuss extreme heat from a planner's perspective, I was unsure of how to address the issue. From a University of Texas at Austin course on hazard mitigation planning with Dr. Robert Paterson, I know that hazard planning in the United States has not kept pace with the academic work on the topic. While searching the University of Texas at Austin library for a book to read over spring break, I came across Stephen Sheppard's book *Visualizing Climate Change*. In his book, Sheppard proposes two aims for planning for climate change. First,

1) "to improve our *vision* and our *insight*: changing how we perceive carbon and its local effects, to open our eyes, make climate change tangible and shake us out of our complacency" (Sheppard, 2012, p. 6).

You already have the vision to act against the impacts of climate change by downloading this professional report based on its title. Sheppard's second aim helped guide my work,

2) "to improve our *foresight*; making it easier for communities to look into their own medium and long-term futures, to make explicit what climate change may mean for them and what collectively can be done about it, thus empowering them to make better choices" (Sheppard, 2012, p. 6).

All planners—whether professionally trained bureaucrats or unpaid neighborhood activists—need to have a basic understanding of the dangers posed by extreme heat events. My original intention for this professional report was to develop a step-by-step playbook for planners writing the extreme heat event section of hazard mitigation plans. I quickly realized that my effort would be futile because the implementation and development of plans are largely a local undertaking that necessitates the input and output of local stakeholders. Rather than seek to develop a playbook, I decided to develop a comprehensive examination of extreme heat events from a planner's perspective. The sheer number of topics, papers, and data sources related to extreme heat events quickly overwhelmed my attempt to outline and research extreme heat events. I felt overburdened by information, and I was only working on this project.

However, I identified a gap in the existing, non-academic literature as I conducted the literature reviews for my initial ideas. While numerous papers and books targeted extreme heat event information towards climatologists, public health experts, and emergency responders, there were few papers geared towards planning professionals. Through this professional report, I attempt to answer the primary question:

- What information about extreme heat events is relevant to the planning profession?

Research Approach

To answer my research question, I conducted an in-depth literature review of published books and papers available through the University of Texas Libraries system, Google Scholar, and United States federal publications. My literature review aimed to identify the current knowledge about the nature of extreme heat events and how planners can best prepare for extreme heat events. I began the literature review by collecting data on the basic history and nature of extreme heat events. As I progressed through this step of the literature review, two important topics emerged: climate change's impact on extreme heat events and social vulnerability during extreme heat events.

I follow up the literature review by applying the information I have learned to a case study of the City of Baltimore's (Maryland) extreme heat event-related planning documents. I have selected Baltimore as a paradigmatic case (Flyvbjerg, 2004). Hazard and disaster resilience experts who investigated and authored the *Beyond the Basics* hazard mitigation research project highlight Baltimore's 2013 multi-hazard mitigation plan as an exemplary plan implementing recommended best practices (Berke & Masterson, 2016b). The case study serves as a reference point for discussion of an approved hazard mitigation plan to the best practices identified in the literature review.

Report Organization

Beyond the introductory chapter, I have divided this report into two distinct sections—Chapters 2 and 3—along with a conclusion summarizing the paper and author's hopes in Chapter 4.

Chapter 2, titled Requisite Extreme Heat Event Knowledge for Planners, is the literature review of key topics planners should understand prior to engaging in extreme heat event hazard mitigation planning. The main topics that Chapter 2 covers are:

- Hazards that may threaten your community
- Multi-hazard mitigation planning legal requirements and best practices
- Extreme heat events— defining and identifying
- Historical context of extreme heat events
- Dangerous futures posed by extreme heat events and why these futures are increasingly threatening
- Human vulnerability to extreme heat events

Chapter 3, titled Case Study: City of Baltimore, Maryland, is my application of the knowledge I gained during the process of researching and writing Chapter 2. I analyze five City of Baltimore planning documents related to hazards. Specifically, I seek to identify extreme heat event planning related to (1) defining extreme heat events, (2) providing local historical context to extreme heat events, (3) drawing a connection between climate change and extreme heat events, and (4) identifying people vulnerable to the effects of extreme heat events. I follow my analysis with a critique of missing elements and suggestions for improving Baltimore's extreme heat event planning process.

Chapter 2 – Requisite Extreme Heat Event Knowledge for Planners

Through my literature review, I attempt to answer the primary research question, “What information about extreme heat events is relevant to the planning profession?” As I read current extreme heat event literature, I noticed a gap between the literature and extreme heat event planning documents. While academics wrestled with defining and describing extreme heat events, most extreme heat event planning documents that I read either glossed over or ignored the definition of extreme heat events and a description of local extreme heat events. Extreme heat event planning documents often recognize the problems posed by climate change and the urban heat island effect on current and future extreme heat events. However, possibly due to the requirements of federal law, these documents rarely speak to the unequal distribution of risk during extreme heat events. An important—but recognized—gap in extreme heat event planning that has been addressed by academic papers and projects for nearly three decades is social vulnerability during extreme heat events.

These gaps between academic papers and planning documents led to two key sub-questions in my quest to answer my primary research question.

1) How can we define extreme heat events from a planner’s point of view?

2) What threat(s) do extreme heat events pose to community well-being?

Figure 1 on page 9 is a flowchart of the literature review topics. I begin with short reviews of hazards and multi-hazard mitigation plans, which I assume are known topics. Then I proceed to review the primary topic, extreme heat events. I begin by reviewing how extreme heat events are defined. After establishing the basics of an extreme heat event definition, I review a brief history of extreme heat events, identify amplifying factors of extreme heat events, and discuss vulnerability during extreme heat events.

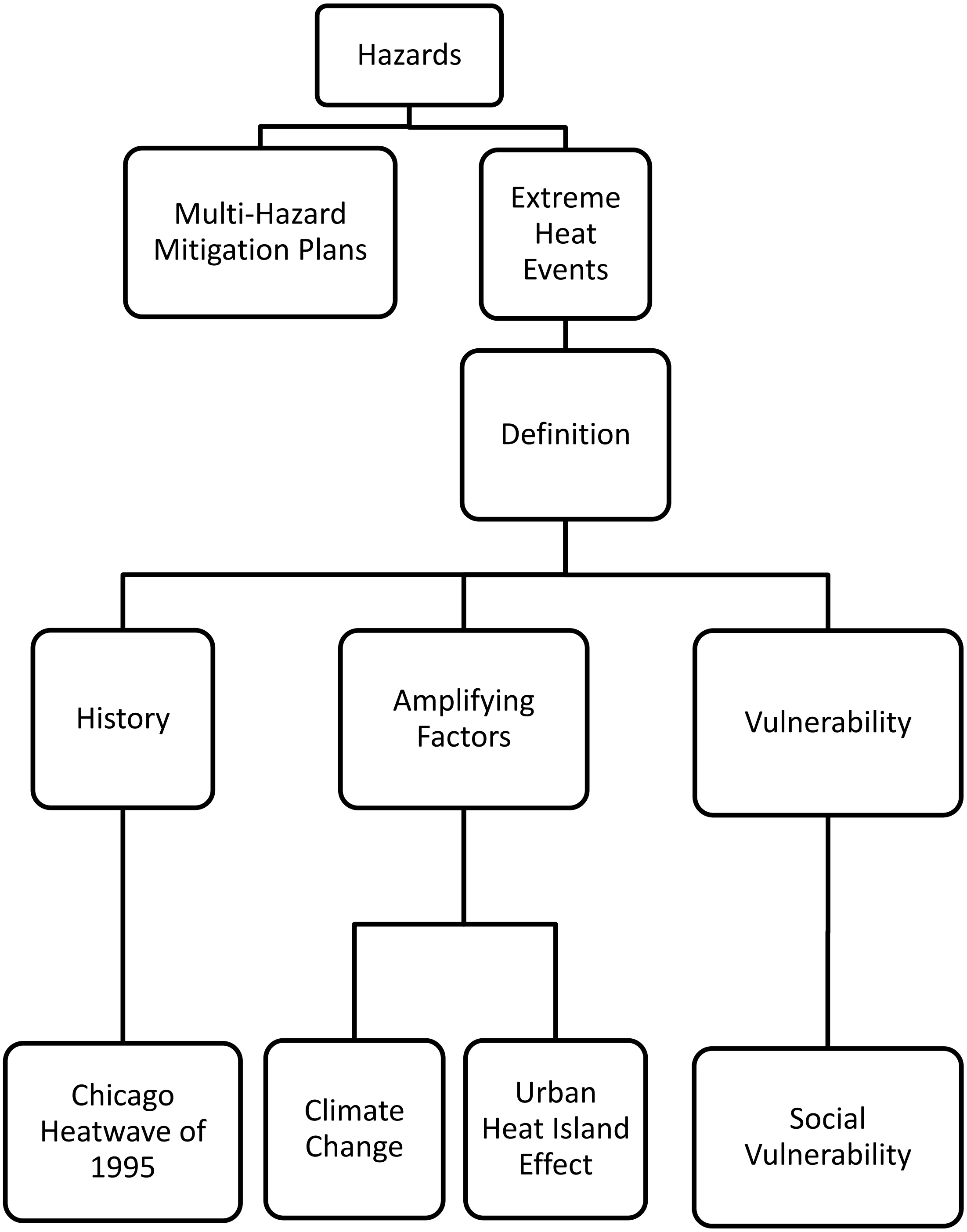

Figure 1: Flowchart of Literature Review Topics
(Andrew Asgarali-Hoffman, 2017)

2.1 – Hazards

Emergency management literature identifies two overarching categories of hazards: natural hazards and human-made hazards (Islam & Ryan, 2015). Natural hazards are further identified by the dominant environmental factor that creates the hazard. Natural hazards fall into the sub-categories of atmospheric hazards, hydrologic hazards, or geologic hazards (Islam & Ryan, 2015, p. 130). Humanmade hazards—also known as technological hazards—are accidental or intentional hazards originating from the "manufacturing, transportation, and use of substances" and materials (Islam & Ryan, 2015, p. 172). FEMA's *Local Mitigation Plan Review Guide* states that the multi-hazard mitigation plan "must address natural hazards," while "[hu]man-made or human-caused hazards may be included in the document, but these are not required and will not be reviewed…" (Federal Emergency Management Agency (FEMA), 2011, p. 19). There is a tension created by FEMA ignoring human-caused hazards and contemporary knowledge on the interaction between humans and natural hazards. While the Earth's forces create natural hazards, human-induced climate change is exacerbating the effects of natural hazards. FEMA's regulation then begs the question, "Where do we draw the line between human-induced natural hazards and natural- natural hazards?" While answering this question is not part of this professional report, planners will be wise to address this tension in their planning documents, especially when planning for extreme heat events[1].

The Local Hazard Mitigation Plan Quality Protocol, an evaluation tool developed by the Center for Sustainable Community Design at the UNC Institute for the Environment and the Center for the Study of Natural Hazards and Disasters at the Department of Homeland Security

[1] For information on the research regarding the effect of climate change on extreme heat events, see section 2.5.A – Climate Change and Extreme Heat Events (pages 30-37).

Coastal Hazards Center of Excellence as part of the *Beyond the Basics*[2] hazard mitigation planning best practices research project, identifies the following hazards for multi-hazard plan inclusion (Center for Sustainable Community Design & Center for the Study of Natural Hazards and Disasters, 2011, p. 7):

- Coastal Erosion
- Drought
- Earthquakes
- Extreme Temperature (Cold)
- Extreme Temperature (Heat)
- Fire
- Floods
- Hurricanes/Coastal Storms
- Landslides
- Sea Level Rise
- Severe Storms
- Subsidence/Sinkholes
- Tornadoes
- Tsunamis
- Volcanoes
- Winter Storms

[2] For more information about the *Beyond the Basics* hazard mitigation planning best practices research project, see pages 14-15 in section 2.2 Multi-Hazard Mitigation Plans.

The Local Hazard Mitigation Plan Quality Protocol evaluation tool also lists climate change, dam failure, and human-made/technological hazards for inclusion in a multi-hazard mitigation plan. However, these three hazards do not meet the emergency management definition of natural hazards. As mentioned above, FEMA will not review these aspects of a multi-hazard mitigation plan even though the *Beyond the Basics* authors determined that inclusion of these hazards in the planning process to be a best practice.

2.2 – Multi-Hazard Mitigation Plans

Extreme heat event planning occurs within the framework of multi-hazard mitigation plans. The Disaster Mitigation Act of 2000 (DMA) is the primary federal legislation guiding hazard mitigation planning. DMA requires states and local governments to receive Federal Emergency Management Administration (FEMA) approval of multi-hazard mitigation plans to be eligible for hazard mitigation grants (Schwab & Topping, 2010, p. 17). DMA seeks to reduce disaster losses by requiring identification of local hazards, risks, and vulnerabilities to encourage hazard mitigation preparation (Schwab & Topping, 2010, p. 17). The Code of Federal Regulations Title 44, Chapter I, Subchapter D, Section 201.6 outlines the requirements for FEMA approval of local multi-hazard mitigation plans under the legislation set by DMA (Local Mitigation Plans Rule, 2009):

i) "An *open public involvement process*" during the drafting stage of the multi-hazard mitigation plan. This planning process must be documented, including information on how it was prepared, which stakeholders were involved, and how the stakeholders were involved.

ii) A *risk assessment* which identifies "the type, location, and extent of all natural hazards that can affect the jurisdiction," including documentation of previous hazard events and predictions for future hazard events. The risk assessment must also "describe vulnerability in terms of" buildings, infrastructure, and critical facilities. The risk assessment serves as the foundation of all proposed mitigation preparations.

iii) The jurisdiction must develop a *mitigation strategy* that serves as the "blueprint for reducing potential losses identified in the risk assessment." This section must identify “a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure.”

iv) A *plan maintenance process schedule* is required to identify how the jurisdiction will monitor and implement the plan before the multi-hazard mitigation plan’s expiration five years after FEMA approval.

v) *Proof that the jurisdiction’s governing body formally adopted the plan* before requesting FEMA approval.

FEMA and the American Planning Association have released multiple guiding documents to assist communities in multi-hazard mitigation planning efforts. These resources can introduce planners unfamiliar with multi-hazard mitigation planning to and through the planning process. FEMA published the *Local Mitigation Planning Handbook* in 2013 to guide the development of multi-hazard mitigation plans under the requirements of 44 CFR §201.6 (Federal Emergency Management Agency (FEMA), 2013). The guide offers exemplary approaches to mitigation planning and implementation. The *Local Mitigation Planning Handbook* serves as a companion to FEMA’s 2011 *Local Mitigation Plan Review Guide*, which is intended to guide officials assessing and approving multi-hazard mitigation plans (Federal Emergency Management Agency (FEMA), 2011). The University of North Carolina at Chapel Hill and Texas A&M University have transformed the *Local Mitigation Planning Handbook* to a website *Beyond the Basics* at MitigationGuide.org. *Beyond the* Basics expands upon FEMA’s guide books by “include[ing] additional examples, address[ing] weaknesses or shortfalls commonly found in hazard mitigation plans, and [suggesting] ways in which mitigation plans could be strengthened” (Berke & Masterson, 2016a). It is important to note that neither DMA nor 44 CFR §201.6 mandate examination of human costs or human vulnerability as requirements for FEMA approval of multi-hazard mitigation plans. Also, neither DMA nor 44 CFR §201.6 require municipalities to address the effect of climate change while developing multi-hazard mitigation plans. The inclusion of human vulnerability and climate change is considered essential best practices by the authors of *Beyond the Basics* (Berke & Masterson, 2016c). Unfortunately, climate change and human vulnerability, both well-researched topics before 2000[3], may not have been included in DMA because of the DMA's Senate author's political biases. Sen. James Inhofe (R-OK) has been titled "the original climate-denier in chief" (Inhofe, 1999; Eilperin & Dennis, 2017).

In addition to above documents, the American Planning Association released Planning Advisory Service (PAS) Report 560 "Hazard Mitigation: Integrating Best Practices into Planning" in 2010, and PAS Report 576, "Planning for Post-Disaster Recovery Next Generation" in 2014. PAS Report 560 is a priming document on hazard mitigation planning for professional planners. The authors sought to advocate for greater involvement of planners in hazard mitigation planning to better integrate hazards as a factor in local plans (Schwab, 2010, p. iv). PAS Report 576 focuses on developing and implementing hazard mitigation strategies through the Federal framework (Schwab, 2014). All four of these guidebooks, while not focused on extreme heat events, should be reviewed before and referenced during all stages of a multi-hazard mitigation planning process.

[3] See sections 2.5.A – Climate Change and Extreme Heat Events (pages 30-37), and 2.6.A – Social Vulnerability (pages 43-48).

2.3 – Extreme Heat Events

> "A heat wave means there are three days—or more—in a row of 90 degree temperatures or higher. That's all it takes in the Ohio Valley." (Ketchmark, 2017)

> "But last week's heat wave was enough to try the patience of even longtime Phoenix residents. It's not that high temperatures of 117 or 115(°F) that were unprecedented—they weren't all time records. But it's August. It's not supposed to be that hot this late in the year." (Johnson, 2015)

If you have experienced outdoor temperatures around 90°F and above 110°F, you can state that both circumstances are uncomfortably hot—both physically and mentally. You may also know from experience that temperatures above 110°F feel hotter and affect your body quicker than a temperature of 90°F. How are Ohioans and Arizonians describing such numerically different temperatures with the same term? This difference is due to the inconsistency among academic researchers in identifying extreme heat events.

Extreme heat events[4] prove difficult to define universally. There are experts who believe that it may be impossible to universally define extreme heat events due to the number of natural and human variables affecting extreme heat event outcomes (Tong, Wang, & Barnett, 2010). The lack of a solid definition can pose a problem for planners undertaking a hazard mitigation planning effort. However, planners, community members, and other stakeholders can determine the extreme heat event definition which best fits their community's needs to identify an extreme heat event, implement emergency procedures, and measure plan effectiveness following the event.

[4] Extreme heat events are also known as heat waves or heatwaves. I will use the term extreme heat event throughout this paper to maintain consistency, unless directly quoting a source that used heat wave.

2.3.A – Attempting to Define Extreme Heat Events

Extreme heat events (also referred to as heat waves) are natural hazards that occur around the globe. A problem posed by extreme heat events is the difficulty in crafting a usable definition from a hazard mitigation viewpoint. Disaster management literature defines heat events as "extended periods of excessive heat and humidity resulting in health threats to the community" (Clements & Casani, 2016, p. 312). The United Nations' Intergovernmental Panel on Climate Change defines extreme heat events as "period[s] of abnormally hot weather" (Intergovernmental Panel on Climate Change, 2012a). The US Environmental Protection Agency provides a narrower definition of extreme heat events by localizing the temperature measurements: "…summertime weather that is substantially hotter and/or more humid than average for a location at that time of year" (Office of Atmospheric Programs, 2016). The Center for Australian Weather and Climate Research built upon the IPCC and EPA definitions by recognizing the importance of duration while expanding the view on the intensity of an extreme heat event: "A period of at least three days where the combined effect of excess heat and heat stress is unusual with respect to the local climate. Both maximum and minimum temperatures are used in this assessment" (Naim & Fawcett, 2013). While these definitions provide a general idea of how an extreme heat event may be recognized, they still rely upon vague heat descriptors such as abnormally, substantially, and unusual. A week of daytime maximum temperatures above 90°F may be normal for Arizona, but these temperatures would be abnormal for Maine.

The research literature does not provide significant clarification. A 2014 effort to provide clarification on the importance of a chosen extreme heat event definition analyzed fifteen quantitative extreme heat event definitions (Smith, Zaitchik, & Gohlke, 2013). The authors noted that while definitions originated from the assumption of "abnormally and uncomfortably hot" weather, there was much variation in the selected metrics, thresholds, and durations by researchers (Smith, Zaitchik, & Gohlke, 2013). When attempting to define extreme heat events, researchers have:

- Selected metrics by using the daily mean temperature (Anderson & Bell, 2011), the daily maximum temperature (Peng et al., 2011; Meehl & Tebaldi, 2004), and the heat index (Grundstein et al., 2012; Rothfusz, 1990).
- Set thresholds as either an absolute threshold (e.g., maximum temperature greater than 105°F (Robinson, 2001) or a relative threshold (e.g., temperatures in the 95th percentile of average temperatures (Anderson & Bell, 2011).
- Required that an extreme heat event can be defined after a single day above the selected metrics and thresholds (Tan et al., 2007) or can be defined only if multiple, sequential days of temperatures above the selected metrics and thresholds occur (Meehl & Tebaldi, 2004).

Many localities rely upon the National Weather Service (NWS) heat event alert system, potentially due to the lack of a precise consensus definition of extreme heat events. The NWS heat event alert system has four tiers of notifications (National Weather Service, n.d.):

1) Excessive heat outlook
    a. This National Weather Service Climate Prediction Center product is a combination of temperature and humidity over a certain number of days. It is designed to indicate areas of the country where people and animals may need to take precautions against the heat during May to November.

2) Heat Advisory

    a. Issued within twelve hours of the onset of the following conditions: heat index of at least 105°F but less than 115°F for less than three hours per day, or nighttime lows above 80°F for two consecutive days.

3) Excessive heat watch

    a. Issued by the National Weather Service when heat indices in excess of 105ºF during the day combined with nighttime low temperatures of 80ºF or higher are forecast to occur for two consecutive days.

4) Excessive heat warning

    a. Issued within twelve hours of the onset of the following criteria: heat index of at least 105°F for more than three hours per day for two consecutive days, or heat index more than 115°F for any period.

It is important to note that heat index is different from temperature. Simplified, the heat index[5] is the "feels like temperature" that measures the interaction between relative humidity and temperature (Samenow, 2011). The heat index is an important measure because humidity causes the body to feel temperatures more intensely.

The NWS alert system has a major shortcoming. The metrics selected for each tier are not localized. A heat index of 105°F or greater—as consistently selected in the NWS heat event alert

[5] Heat index is a measurement of how hot it feels for a human. The full heat index equation involves twenty-two variables: "vapor pressure, dimensions of a human, effective radiation area of skin, significant diameter of a human, clothing cover, core temperature, core vapor pressure, surface temperatures and vapor pressure of skin and clothing, activity, effective wind speed, clothing resistance to heat transfer, clothing resistance to moisture transfer, radiation from the surface of the skin, convection from the surface of the skin, sweating rate, ventilation rate, skin resistance to heat transfer, skin resistance to moisture transfer and surface resistance to moisture transfer" (Samenow, 2011). The National Weather Service has simplified the heat index equation into a chart (see Figure 2 on page 20) that determines the heat index based on the measured temperature and percent humidity (Samenow, 2011).

system definitions—is dangerous for the human body (see Figure 2 on page 20) (National Weather Service, 2001). This absolute cut-off fails to account for the fact that some people begin to experience negative health effects at temperatures less than 105°F. Even though researchers have struggled to identify a universal metric for identifying extreme heat events, prior public health research has associated 85th percentile heat indexes with increased heat-related mortalities (Kalkstein & Davis, 1989; Stone, Hess, & Frumkin, 2010).

Heat Index

Relative Humidity (%)

Temperature (°F)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
80	77	78	78	79	79	79	80	80	80	81	81	82	82	83	84	84	85	86	86	87
81	78	79	79	79	79	80	80	81	81	82	82	83	84	85	86	86	87	88	90	91
82	79	79	80	80	80	80	81	81	82	83	84	84	85	86	88	89	90	91	93	95
83	79	80	80	81	81	81	82	82	83	84	85	86	87	88	90	91	93	95	97	99
84	80	81	81	81	82	82	83	83	84	85	86	88	89	90	92	94	96	98	100	103
85	81	81	82	82	82	83	84	84	85	86	88	89	91	93	95	97	99	102	104	107
86	81	82	83	83	83	84	85	85	87	88	89	91	93	95	97	100	102	105	108	112
87	82	83	83	84	84	85	86	87	88	89	91	93	95	98	100	103	106	109	113	116
88	83	84	84	85	85	86	87	88	89	91	93	95	98	100	103	106	110	113	117	121
89	84	84	85	85	86	87	88	89	91	93	95	97	100	103	106	110	113	117	122	
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91	85	86	87	87	88	89	90	92	94	97	99	102	105	109	113	117	122	126	132	
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93	87	88	89	89	90	92	93	95	98	101	104	107	111	116	120	125	130	136		
94	87	89	90	90	91	93	95	97	100	103	106	110	114	119	124	129	135	141		
95	88	89	91	91	93	94	96	99	102	105	109	113	118	123	128	134	140			
96	89	90	92	93	94	96	98	101	104	108	112	116	121	126	132	138	145			
97	90	91	93	94	95	97	100	103	106	110	114	119	125	130	136	143	150			
98	91	92	94	95	97	99	102	105	109	113	117	123	128	134	141	148				
99	92	93	95	96	98	101	104	107	111	115	120	126	132	138	145	153				
100	93	94	96	97	100	102	106	109	114	118	124	129	136	143	150	158				
101	93	95	97	99	101	104	108	112	116	121	127	133	140	147	155					
102	94	96	98	100	103	106	110	114	119	124	130	137	144	152	160					
103	95	97	99	101	104	108	112	116	122	127	134	141	148	157	165					
104	96	98	100	103	106	110	114	119	124	131	137	145	153	161						
105	97	99	102	104	108	112	116	121	127	134	141	149	157	166						
106	98	100	103	106	109	114	119	124	130	137	145	153	162	172						
107	99	101	104	107	111	116	121	127	134	141	149	157	167							
108	100	102	105	109	113	118	123	130	137	144	153	162	172							
109	100	103	107	110	115	120	126	133	140	148	157	167	177							
110	101	104	108	112	117	122	129	136	143	152	161	171								
111	102	106	109	114	119	125	131	139	147	156	166	176								
112	104	107	111	115	121	127	134	142	150	160	170	181								
113	104	108	112	117	123	129	137	145	154	164	175									
114	105	109	113	119	125	132	140	148	158	168	179									
115	106	110	115	121	127	134	143	152	162	173	184									
116	107	111	116	122	129	137	146	155	166	177										
117	108	112	118	124	132	140	149	159	170	181										
118	108	113	119	126	134	142	152	162	174	186										
119	109	114	121	128	136	145	155	166	178											
120	110	116	122	130	138	148	158	170	182											
121	111	117	124	132	141	151	162	174	187											
122	111	118	125	134	143	154	165	178												
123	112	119	127	136	146	157	169	182												
124	113	120	129	138	148	160	172													
125	114	121	130	140	151	163	176													

Extreme Danger	Heat stroke likely.
Danger	Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	Fatigue possible with prolonged exposure and/or physical activity.

Figure 2: National Weather Service Heat Index Chart
(National Weather Service, n.d.)

While researchers continue to work towards identifying a universal extreme heat event definitions, planners should know the following: extreme heat is dependent upon local mean temperatures and maximum heat indexes; decision makers can be conservative or liberal with risk by declaring extreme heat events on a day-by-day basis or require a projected multiple day duration of extreme heat before declaring an extreme heat event.

2.4 – Brief History of Extreme Heat Events

Extreme heat events are not a recent phenomenon uniquely attributable to human-induced climate change. The earliest extreme heat event—that I located—dates from the year 1252 in the south of England from a nun's written records. The nun wrote of an excessive heat event causing an excessive number of deaths, including the deaths of three abbots and the mother of King Louis of France (Burton, 2011).While there are attempts being made by academics to catalogue historical disasters (e.g., Marusek, 2011) and meteorological records dating to before the 20th Century, (e.g., Smithsonian Institution, 2012, and National Weather Service Public Affairs Office, 2004), the standardization of meteorology in the early 20th Century is attributed for primarily reporting weather events that occurred after 1900 (Saner, 2007).

Extreme heat events are among the deadliest disasters to affect the United States. There have been 3,979 extreme heat event causalities since the National Weather Service began tracking extreme heat event fatalities in 1986 (National Weather Service Public Affairs Office, 2017). This number may be greatly underreported because extreme heat event mortality is best measured as local excess mortality in a given period, although the magnitude and effect of this potential underreporting is not known (Dixon et al., 2005, p. 940; U.S. Environmental Protection Agency, 2016; World Health Organization Regional Office for Europe, 2008, p. 17). In comparison to the other hazard event fatalities tracked by the National Weather Service, extreme heat events are historically the 4th deadliest hazard events in gross fatalities (see Table 1 on page 23). Although hurricane fatalities have been tracked since 1940, there are fewer gross hurricane fatalities than extreme heat event fatalities. Extreme heat events are the deadliest hazard to affect the United States in the past thirty years with an average annual death toll of 130, and in the past ten years with an average annual death toll of 110 (see Table 1 on page 23).

Hazard Fatality from United States-based Events				
Hazard	**First Year Tracked**	**Gross Fatalities**	**30-Year Average (1986-2016)**	**10-Year Average (2006-2016)**
Extreme Heat Events	1986	3,979	130	113
Floods	1940	7,942	82	86
Hurricanes	1940	3,348	46	4
Lightning Strikes	1940	9,311	48	31
Tornadoes	1940	7,599	70	110
Terrorism*	1986	3,348	115**	12***
*Terrorism data not yet available for 2016. Data range 1986 to 2015 **29-Year Average (1986-2015) ***10-Year Average (2005-2015)				
Sources: National Weather Service Public Affairs Office, 2017; National Consortium for the Study of Terrorism and Responses to Terrorism, 2017				

Table 1: Fatality Counts by Hazard from United States-based Disaster Events

It is important to note that the two deadliest extreme heat events in United States' history are not included in the National Weather Service's official data. The Université catholique de Louvain *Emergency Events Database*—a comprehensive disaster database documenting occurrences, mortality figures, and estimated economic damage—identifies a 1980 extreme heat event resulting in 1,260 fatalities and a 1936 extreme heat event resulting in 1,193 fatalities as the two deadliest extreme heat events in the United States (see Table 2 below).

Eight Deadliest Extreme Heat Events in the United States (1900-2017)	
Year	**Number of Deaths**
1980	1,260
1936	1,193
1995	670
1999	257
1983	188
1966	182
2006	164
1998	130
Source: Centre for Research on the Epidemiology of Disasters & Sapir, 2017	

Table 2: Eight Deadliest Extreme Heat Events in the United States (1900-2017)

Extreme heat events far deadlier than the 1,000+ fatality U.S.-based events have been recorded. The Russian extreme heat event of 2010 ranks as the deadliest extreme heat event with at least 55,736 deaths attributed to this catastrophe. This extreme heat event killed nearly three times more people than the second deadliest extreme heat event (in Italy, 2003) and was nearly 44 times deadlier than the United States' deadliest extreme heat event (in 1980). It is important to note that the world's ten deadliest extreme heat events have occurred within the past twenty years (see Table 3 below).

Eight Deadliest Extreme Heat Events in the World (1900-2017)		
Year	**Country**	**Number of Deaths**
2010	Russia	55,736
2003	Italy	20,089
2003	France	19,490
2003	Spain	15,090
2003	Germany	9,355
2015	France	3,275
2003	Portugal	2,696
1998	India	2,541
Source: Centre for Research on the Epidemiology of Disasters & Sapir, 2017		

Table 3: Eight Deadliest Extreme Heat Events in the World (1900-2017)

2.4.A – Chicago Heat Wave of 1995

Note: Eric Klinenberg's dissertation-to-book "Heat Wave: A Social Autopsy of Disaster in Chicago" is an acclaimed in-depth study of Chicago's 1995 extreme heat event.

The Chicago Heat Wave of 1995 is the third deadliest recorded extreme heat event in the United States. At least 739 Chicagoans died over the weeklong extreme heat event in July 1995 with a majority of the fatalities attributed to the over a three-day stretch of intense heat from July 13th through 15th (Thomas, 2015). The death toll places the Chicago Heat Wave of 1995 as the 17th deadliest mass casualty event to impact the United States (Climate Signals, 2016).

Figure 3: An exhausted emergency responder rests against a car

(Phil Greer, 1995)

Meteorology science in 1995 was already able to predict extreme heat events accurately. Newspapers and newscasters warned Chicagoans that the approaching heat wave meant it was time to "use air conditioners, drink plenty of water each day, and relax" (Klinenberg, 2015, p. 1). These light-hearted warnings from the media did not prepare Chicagoans and social service providers for the intensity of the event.

Services important to the functioning of normal, safe life routines could not handle the volume of service demands placed upon them. School buses stuck in rush hour traffic soon became medical emergency scenes as students began suffering from heat exhaustion (Klinenberg, 2015, p. 1). The power grid failed throughout the city due to the extraordinary demand placed upon the grid, mostly attributable to the air conditioners recommended by the news media (Klinenberg, 2015, p. 3). Children, especially those living in impoverished neighborhoods, attempted to cool down by opening fire hydrants. The widespread occurrence of thousands of open fire hydrants caused water pressure failure throughout the city, leaving entire buildings without water for days (Klinenberg, 2015, p. 5). Emergency services and hospitals could not handle the volume and intensity of calls being placed upon medical responders. Emergency services received over 16,000 service calls on the first day of the heat wave in comparison to the average daily volume of 10,000 service calls (Ihejirika, 2016). During the most intense days of the heat crisis, twenty-three hospitals instituted bypass status, or when a health care facility declares itself full and informs local emergency services that the facility cannot admit new patients (Klinenberg, 2015, p. 138; Segen, 2002). At one point, eighteen hospitals were on bypass status (Klinenberg, 2015, p. 138). The at-capacity hospitals placed further stress upon ambulance crews as the Chicago Fire Department’s command structure was unaware of this breakdown, and it had no system in place to inform drivers of which emergency rooms were open or closed (Klinenberg, 2015, p. 6 and 138).

Figure 4: Chicago paramedics respond to a heat-related emergency involving an elderly victim

(Walter Kale, 1995)

The most drastic scene of devastation occurred at the Cook County morgue. The speed and volume of deceased bodies brought to the morgue quickly overwhelmed it. A reporter described police officers waiting in line for more than an hour and a half before a morgue worker could assist in unloading the deceased from the officer's car (Klinenberg, 2015, p. 149). A local meat packing plant owner volunteered his fleet of nine refrigerated transport trucks to serve as cadaver storage (see Figure 5 on page 29) (Klinenberg, 2015, p. 8)

Figure 5: Cook County morgue workers walk between rows of refrigerated trucks outside the morgue

(Mike Fisher, 1995)

The social autopsy of the Chicago Heat Wave of 1995 highlights two human-created errors that amplified the death toll. Chicago's politicians and bureaucrats did not appropriately prepare for the event, while the news media largely allowed this mistake to go unanswered. Social isolation and structural poverty largely determined the people who died during the extreme heat event. Properly planning and implementing multi-hazard mitigation plans can help prevent a city from experiencing avoidable disasters such as the Chicago Heat Wave of 1995. More important than knowing the history of Chicago's Heat Wave of 1995 (unless you are Chicago) is knowing your local history of extreme heat events and how your city services were able or not able to appropriately respond to the needs of the community.

2.5 – Amplifying Factors

Researchers predict a significant increase in the frequency, intensity, and duration of extreme heat events across the globe. This change is largely attributed to two major activities: global climate change and the urban heat island effect. Understanding the risk posed by extreme heat events and how to develop mitigation strategies means that planners must understand these two amplifying factors. This section will focus on the predicted future of extreme heat events under climate change, and on how the urban heat island effect multiplies the destructive risk posed by extreme heat events.

2.5.A – Climate Change and Extreme Heat Events

The Earth is warming. A 2013 comprehensive review of peer-reviewed journal articles on ‘global climate change’ or ‘global warming’ published between 1991 and 2011 found that 97.1% of the articles concluded that global warming is occurring (Cook et al., 2013). Since 2013, the globe has experienced its three hottest years since 1880, with 2015 and 2016 the first years to be more than 1.5°F over the 20^{th} century’s average temperature (see Figure 6 on page 31) (Climate Central, 2017). As of the time of writing in July 2017, the 2017 calendar year is on pace to displace 2015 as the second hottest year on record (Thompson, 2017).

Figure 6: The Globe's Ten Hottest Years on Record, since 1880
(Climate Central, 2016)

A point of contention often revolves around global and regional climate differences. Every square mile of the Earth is not necessarily experiencing above average temperatures, and this does not negate the science of climate change and global warming. However, with intense nationalistic pride in the United States, it can be beneficial to look at the United States without examining the global whole. The United States' National Oceanic and Atmospheric Administration (NOAA) divides the continental United States into 344 climate divisions (National Centers for Environmental Information, n.d.). Of these climate divisions, 314 experienced increases in average summer temperature from 1970 to 2014 (Climate Central, 2015). NOAA further condenses the climate divisions into nine climate regions. All nine climate regions experienced average summer temperature increases—ranging from 2°F (the Ohio Valley and the Northern Rockies and Plains) to 3.6°F (the Southwest)—from 1970 to 2014 (Climate Central, 2015). Figure 7 on page 33 illustrates the general warming of nearly every portion of the United States—the continental 48 states plus Alaska and Hawaii.

Rate of Temperature Change in the United States, 1901-2008

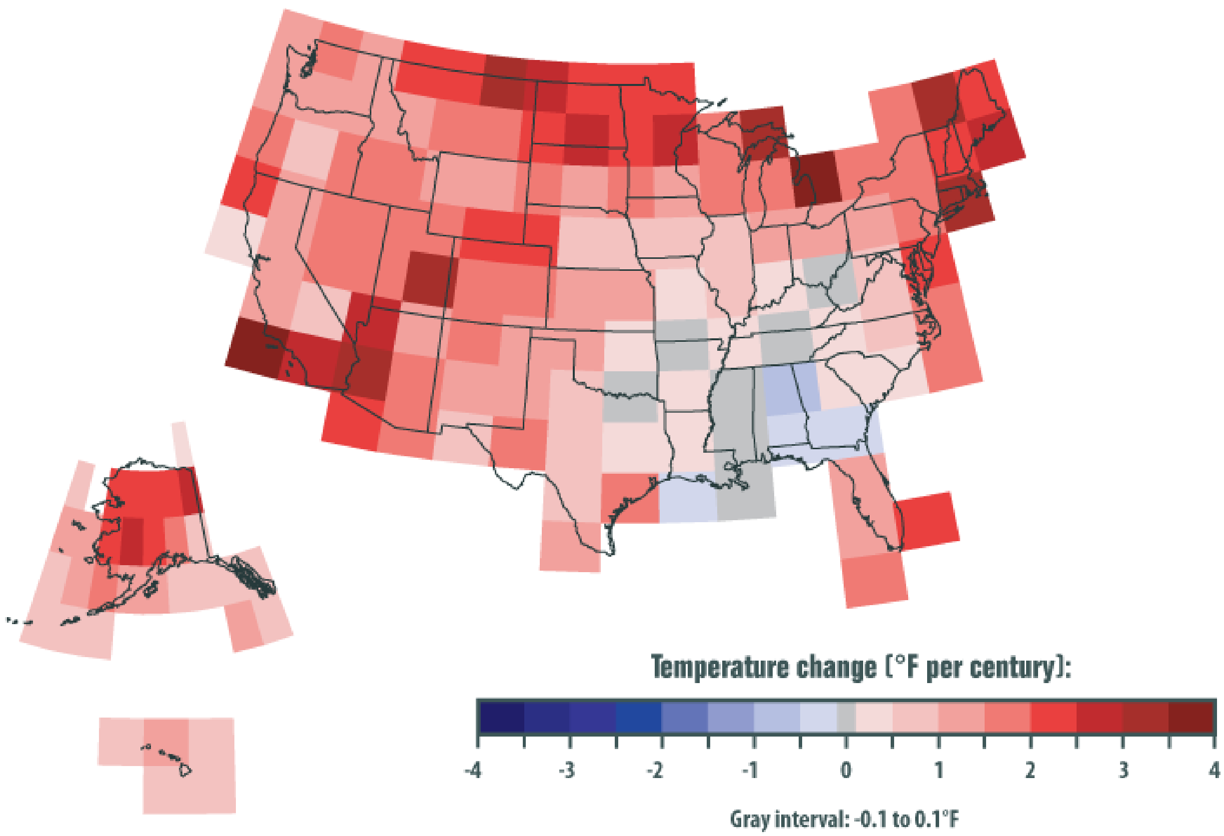

Figure 7: Rate of Temperature Change in the United States, 1901-2008 (Centers for Disease Control and Prevention, n.d.)

The rise in average temperature increases the risk of extreme heat events. Extreme heat events are predicted to increase in frequency, intensity, and duration (Karl, Melillo, & Peterson, 2009; Meehl et al., 2007; Centers for Disease Control and Prevention, n.d.).

If annual global greenhouse gas emissions do not significantly drop (which is even more probable now given the United States' 2017 withdrawal from the Paris Climate Accord), many Americans face a greatly increased risk of heat danger days. Heat danger days are days where the official heat index tops 105°F and reflect the intensity of extreme heat (National Weather Service, 2001). Between 1950 and 2015, only twelve of the largest 144 U.S. cities experienced, on average, more than one heat danger day per year (Kahn, 2015). By 2050, 141 of the largest U.S. cities are projected to have more than one heat danger day per year, on average (Kahn, 2015). This count includes 111 cities projected to experience twenty or more heat danger days per year (Kahn, 2015). Table 4, see below, lists the ten cities facing the greatest risk based upon the projected number of heat danger days in 2050.

Top 10 U.S. Cities Facing the Most Danger Days			
Rank	**City**	**Danger Days by 2050**	**Average Annual Dangers Days (2000-2009)**
1	Brownsville, Texas	167	0.1
1	Phoenix, Arizona	167	22
3	Miami, Florida	157	0
4	Corpus Christi, Texas	150	0.4
5	Tampa, Florida	145	0
6	Tucson, Arizona	140	0.7
7	San Antonio, Texas	138	0.2
8	Austin, Texas	137	1.3
9	Las Vegas, Nevada	131	10
10	Houston, Texas	129	0.3
Source: Kahn, 2015			

Table 4: Estimated Heat Danger Days if Global GHG Emissions Not Reduced

The United Nation’s International Panel on Climate Change A2 emissions scenario is considered the most probable scenario for a hotter future given current efforts to combat climate change (AdaptNSW, n.d.). Climate projections predict that most Americans will experience extreme heat events that last ten to twenty days longer than present-day extreme heat events (see Figure 8 below) (Centers for Disease Control and Prevention, n.d.; National Research Council, 2011). The Chicago Heatwave of 1995 lasted only three days.

Predicted Extreme Heat Event Duration by Projected Increase in Average Temperature

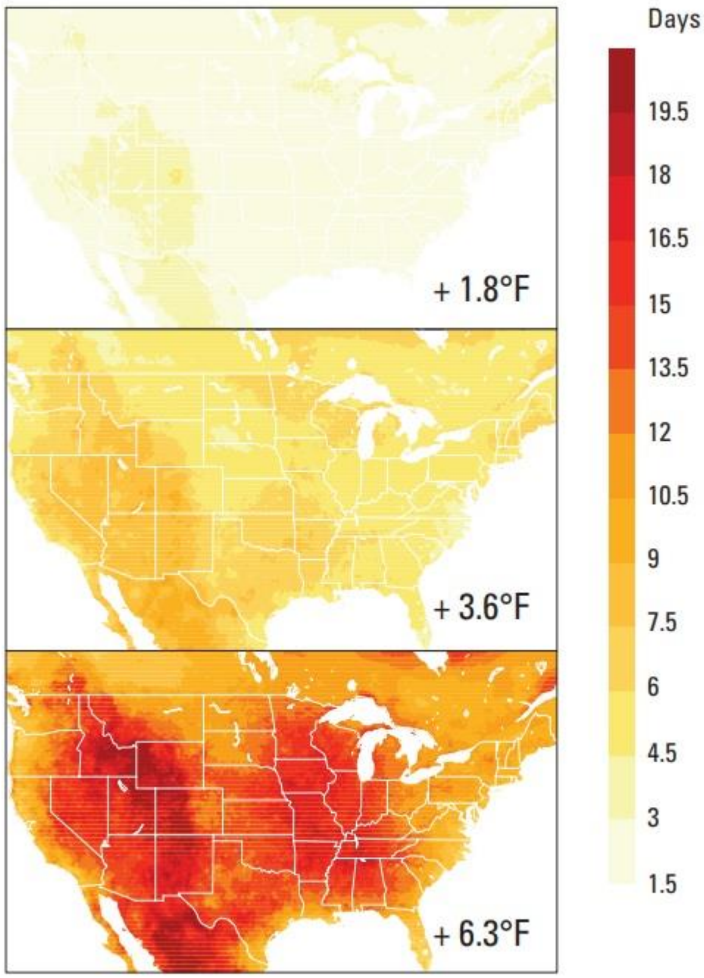

Figure 8: Projected increase in the number of days per extreme heat event of the longest event each year under the most likely future global greenhouse gas emissions scenario. (Centers for Disease Control and Prevention, n.d.)

An interactive mapping dashboard created by Climate Central illustrates the predicted summer high temperatures under unabated climate change of 1,001 US cities as a geographic comparison of current summer temperatures to a different city. By 2100, New York City summer average high temperatures will be comparable to current summer average high temperatures in Lehigh Acres, Florida (Climate Central, 2014). By 2100, Lehigh Acres summer average high temperatures will be comparable to current summer average high temperatures in Mission, Texas (Climate Central, 2014). By 2100, Mission summer average high temperatures will be comparable to current summer average high temperatures in Yuma, Arizona (Climate Central, 2014). By 2100, Yuma summer average high temperatures will be comparable to current summer average high temperatures in Kuwait City, Kuwait (Climate Central, 2014). The current summer average high temperature in Kuwait City is 114°F, which is currently mean highest summer temperature experienced by Yuma (Climate Central, 2014; Wikipedia, 2017). See Figure 9 on page 37 for illustrated geographic comparison of future summer temperatures in New York City, Lehigh Acres, Mission, and Yuma.

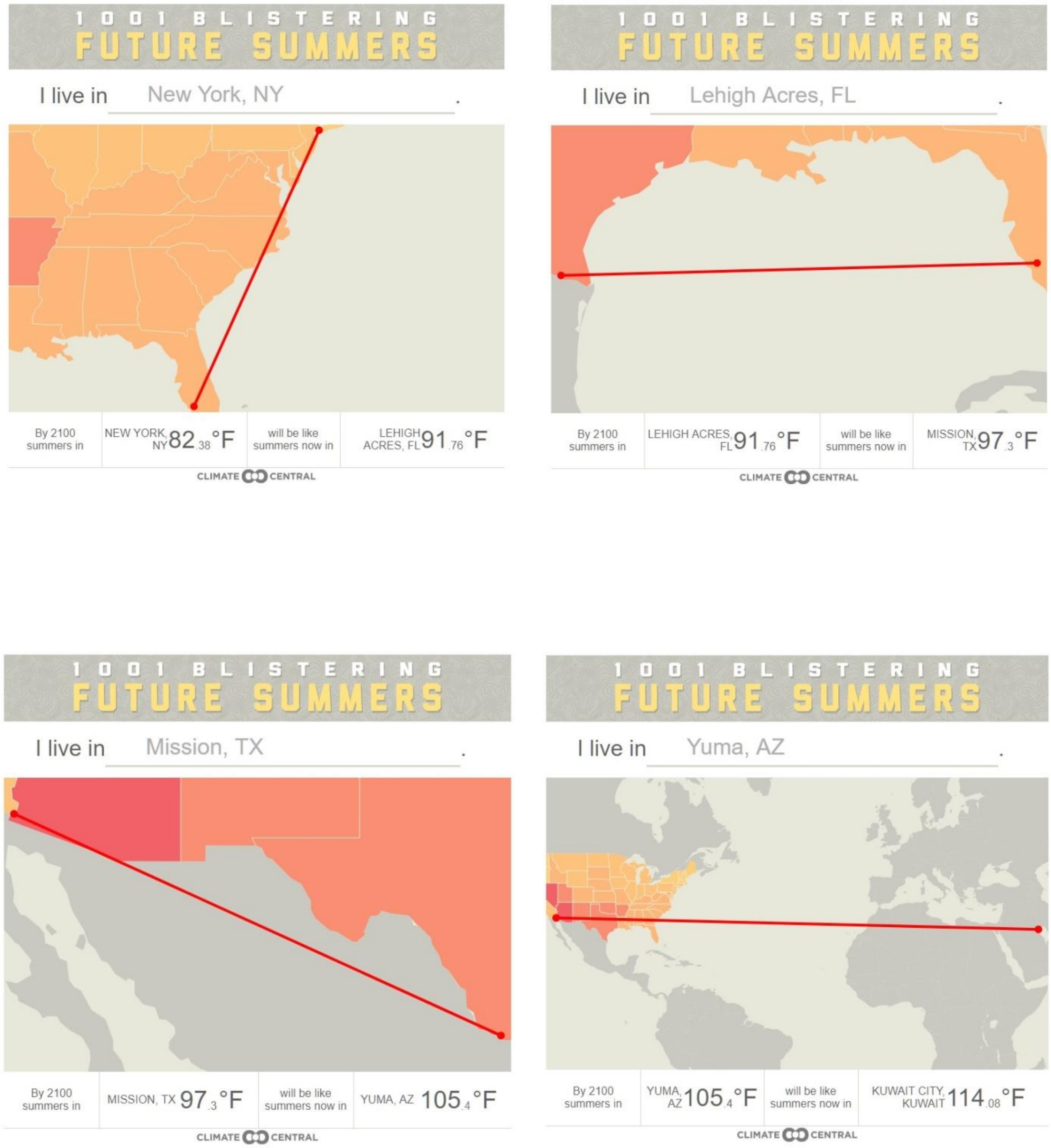

Figure 9: Mapped comparison of cities' projected future summer high temperatures to a city's current summer high temperatures under unabated climate change.
(Climate Central, 2014)

2.5.B – Urban Heat Island Effect

The urban heat island effect is a well-studied and well-documented built environment phenomenon (Oke, 1973; Katsoulis & Theoharatos, 1985; Balling & Cerveny, 1987; Lee, 1992; Saitoh, Shimada, & Hoshi, 1996; Yamashita, 1996; Böhm, 1998; Figuerola & Mazzeo, 1998; Kłysik & Fortuniak, 1999; Kim & Baik, 2002; Wilby, 2003; Mirzaei & Haghighat, 2010; Tan et al., 2010). The urban heat island effect is a measurable positive difference in temperatures of urban areas compared to neighboring rural and suburban areas within a metropolitan area. Annually, the mean temperature difference between urban and rural areas is a measured difference of 1.8 to 5.4°F higher in urban areas (U.S. Environmental Protection Agency, 2008a). The urban heat island effect tends to be most intense at night time when temperature differences as great as 22°F are observed between neighboring urban and rural areas (U.S. Environmental Protection Agency, 2008a). This effect is largely attributed to three processes: deforestation, urbanization, and pollution. The deforestation of urban environments removes trees that would cool the environment through shade and evapotranspiration (University Corporation for Atmospheric Research, 2011). The structure and materials of the urban built environment can block the cooling effect of winds while trapping (e.g., impervious surfaces reducing the cooling effects of evaporation and tall, dense clusters of buildings trapping radiant heat in "urban canyons") and releasing radiant heat (e.g., air conditioners transporting heat from building interiors to the environment) (Ramamurthy & Bou-Zeid, 2014; Salamanca, Georgescu, Mahalov, Moustaoui, & Wang, 2015; University Corporation for Atmospheric Research, 2011). The burning of fossil fuels releases anthropogenic heat into the environment while the exhaust creates a layer of haze that impedes the release of thermal radiation from the urban climate (University Corporation for Atmospheric Research, 2011).

Urban heat island effect mitigation is a popular method of planning for extreme heat events. It is an important task because the percentage of human population affected by the urban heat island effect is likely to expand rapidly over the coming decades. It is predicted that at least 60% of the global population will reside in cities by 2030 (Population Reference Bureau, 2007). Rapid urbanization will coincide with large scale growth of the built environment that will increase the urban heat island effect if growth is planned haphazardly (Mirzaei & Haghighat, 2010). Rapid urbanization poses a risk ongoing planning efforts if the growth overwhelms the capacity of the city to provide for the new population (Pelling, 2003, p. 44). It should be noted that current best practices of mitigating the urban heat island effect do not require governments to grapple with systemic social issues underlying the social vulnerability of extreme heat events. The focus on infrastructure mitigation is more politically palatable and allows for easier proof of progress than social reform or resource redistribution (Pelling, 2003, p. 49).

Urban heat island effect mitigation strategies primarily consist of grey and green infrastructure improvements by increasing vegetative cover and resurfacing heat absorbing impermeable surfaces (Shickman & Garg, 2016). The afforestation of urbanized areas provides cooling effects through shade and evapotranspiration if the plants are properly selected and located for the local climate (U.S. Environmental Protection Agency, 2008b). Recognizing that the highly urbanized areas may lack ground space for afforestation, green roofs introduce vegetation through carefully cultivating a vegetative layer on rooftops (U.S. Environmental Protection Agency, 2008c). Impermeable surfaces dominate the urbanized landscapes. Cool roof and pavement technologies replace the heat absorbing asphalt and tar surfaces to reduce surface temperatures and overnight ambient temperatures. Cool roofing technology increases the energy efficiency of buildings by reflecting the majority of solar energy received at a lower thermal equilibrium. Research demonstrates that the average cool roof reaches a summertime peak temperature of 115°F compared to 185°F for the average black asphalt roof (U.S. Environmental Protection Agency, 2008d). Cool pavements apply the same concept to the urban environments' most common land cover—pavement (U.S. Environmental Protection Agency, 2012). Both cool roofs and cool pavements reduce the peak surface temperatures experienced by humans, animals, and vegetation while reducing the ambient temperature the results from the overnight release of stored heat.

The EPA published an in-depth policy guide *Reducing Urban Heat Islands: Compendium of Strategies* (U.S. Environmental Protection Agency, 2017). This report lays out the basics of the urban heat island effect, provides mitigation strategies along with cost-benefit analysis, and lays out policy recommendations for comprehensive plans as well as zoning and building codes. A second, less comprehensive—but reader-friendly—resource is the C40 Cities Climate Leadership Group's *Good Practice Guide: Cool Cities* (C40 Cities Climate Leadership Group, 2016). In addition to providing a basic background on the urban heat island effect, the C40 *Good Practice Guide: Cool Cities* provides best practice case studies of mitigation strategies.

2.6 – Vulnerability

Disasters are the result of the continuous interaction between society, the built environment, and the threat of natural hazards. Given the threat of a hazard, vulnerability is "the diminished capacity of an individual or a group to anticipate, cope with, resist and recover from the impact of a…hazard" (International Federation of Red Cross and Red Crescent Societies, 2010). Economically and politically marginalized communities are the most vulnerable in the face of threats posed by hazard events (Pelling, 2003, p. 3). This vulnerability is the result of the unequal and inequitable growth of communities' power within the national and global economy (Pelling, 2003, p. 168).

Disasters are not one-off events that randomly occur outside of the reach of policy decisions (Pelling, 2003, p. 47). Vulnerability can refer to the physical vulnerability of the built environment (buildings, infrastructure, and critical facilities), economic vulnerability, and human vulnerability. In the United States, vulnerability assessments are skewed towards physical vulnerability and economic vulnerability because the Disaster Mitigation Act of 2000 requires the risk assessment section of multi-hazard mitigation plans to describe vulnerability from the perspective of buildings, infrastructure, and critical facilities (Local Mitigation Plans Rule, 2009). Although analysis of social vulnerability is considered a hazard mitigation planning best practice by the authors of the *Beyond the Basics* research project, multi-hazard mitigation plans can be approved without social vulnerability analysis (Berke & Masterson, 2016d; Local Mitigation Plans Rule, 2009).

Extreme heat events cause damage to buildings, infrastructure, and critical facilities. Flights in Phoenix, Arizona, were grounded during the summer of 2017 due to ambient air temperatures that made it unsafe for airplanes to take-off (Kelly, 2017). Extreme heat can damage transportation infrastructure. These can lead to costly service shutdowns for emergency repairs. A wave of extreme heat events in 2012 formed a heat kink in a Washington Metro Green Line track leading to a train derailment (see Figure 10) and buckled highway pavement during rush hour in Raleigh, North Carolina (see Figure 11) (Trautman, 2012; WRAL, 2012).

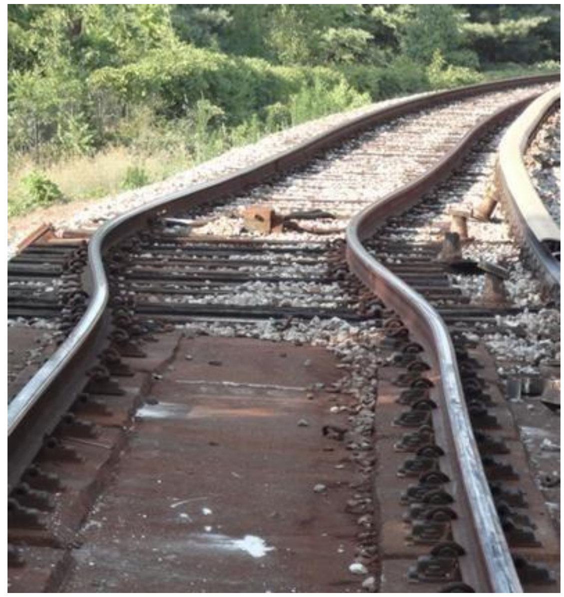

Figure 10: Heat kink on a Washington Metro Green Line track
(WMATA, 2012)

Figure 11: North Carolina work crew repairs highway buckled by extreme heat
(Travis Long, 2012)

However, unlike other natural disasters such as earthquakes or hurricanes, the physical and economic vulnerability is not the primary concern during extreme heat events. As stated earlier, extreme heat events are the deadliest natural disasters in the United States over the past thirty years. Therefore, social vulnerability, or the human cost, is the primary concern during extreme heat events.

2.6.A – Social Vulnerability

Vulnerability research has only recently focused on the societal-environmental interaction of hazard events. Early research defined vulnerability as "the degree to which a system acts adversely to the occurrence of a hazardous event [with]…the adverse reaction…conditioned by the system's resilience" (Timmerman, 1981; Cutter, 1996). The research definition of vulnerability had evolved to include the social dimension by the early 1990s. Susan Cutter, a researcher at the University of South Carolina and an important figure in hazard mitigation research, defined vulnerability as "the likelihood that an individual or group will be exposed to and adversely affected by a hazard" and is a result of "the interaction of the hazards of place with the social profile of communities" (Cutter, 1993; Cutter 1996). Cutter and colleagues understood vulnerability through three main dimensions (Cutter, Boruff, & Shirley, 2003):

(1) exposure to certain conditions make people and places vulnerable (Burton, Kates, & White, 1993; Anderson, 2004)

(2) vulnerability is a social condition measuring societal resistance or resilience to hazards (Blaikie, Cannon, Davis, & Wisner, 1994; Hewitt, 1997)

(3) exposure and societal resistance/resilience vary between and within places and regions (Kasperson, Kasperson, & Turner, 1995; Cutter, Mitchell, & Scott, 2000)

This understanding is becoming an important paradigm for planners and emergency managers as they attempt to grapple with an increased frequency of disasters (Dolan & Messen, 2012). The development of aocial vulnerability indices provide planners and policy makers with the ability to identify—before a disaster—communities with a diminished capacity to anticipate, cope with, resist, and recover from a disaster event.

While *Beyond the Basics* provides a short list of plans incorporating social vulnerability, there does not seem to be a count of the current number of plans integrating social vulnerability indices into their hazard mitigation planning efforts. Based off my observations from reading and skimming hazard mitigation plans, I believe social vulnerability indices are an underutilized tool.

Social vulnerability indices are tools developed to identify the communities most vulnerable to hazard events, whether it is a single hazard or general hazard vulnerability. Developed by researchers at academic and government institutions, these tools use statistical analysis to identify measures of Census data that correlate with social vulnerability to develop formulas that can be mapped in geographic information system programs. I cover three social vulnerability indices in this professional report. Cutter's Social Vulnerability Index—the original social vulnerability index—which identifies general hazard vulnerability at the county level. The Extreme Heat Vulnerability Index which identifies extreme heat event hazard vulnerability at the Census block level. The Centers for Disease Control and Prevention's Social Vulnerability Index which identifies general hazard vulnerability at the Census tract level.

In 2003, Cutter sought to develop an index to better identify and track populations most vulnerable to hazards using previously collected data. Using the "general consensus within the social science community" about the primary identifiers of vulnerable populations, Cutter was able to identify eleven factors (see Table 5 on page 45) which explained 76.4% of the variance in levels of social vulnerability—or the ability to anticipate, cope with, resist, and recover from a disaster event— at the county level (Cutter, Boruff, & Shirley, 2003, p. 251). Cutter scaled the factors, so positive correlation values indicate higher levels of vulnerability, and negative correlation values indicate lower levels of vulnerability (Cutter, Boruff, & Shirley, 2003, p. 254). Cutter's Social Vulnerability Index (SoVI) works as a general measure of a community's social vulnerability to hazards. Through the Social Vulnerability Index's design, planners are not able to apply the index to identify community's social vulnerability to specific hazards. To address this weakness, scholars have used Cutter's work as a reference point in designing hazard-specific vulnerability indices.

Susan Cutter's Dimensions of Social Vulnerability				
Factor	Name	Percent Variation Explained	Dominant Variable	Correlation
1	Personal wealth	12.4	Per capita income	+0.87
2	Age	11.9	Median age	-0.90
3	Density of the build environment	11.2	No. commercial establishments/mi^2	+0.98
4	Single-sector economic dependence	8.6	% employed in extractive industries	+0.80
5	Housing stock and tenancy	7.0	% housing units that are mobile homes	-0.75*
6	Race—African American	6.9	% African American	+0.80
7	Ethnicity—Hispanic	4.2	% Hispanic	+0.89
8	Ethnicity—Native American	4.1	% Native American	+0.75
9	Race—Asian	3.9	% Asian	+0.71
10	Occupation	3.2	% employed in service occupations	+0.76
11	Infrastructure dependence	2.9	% employed in transportation, communication, &public utilities	+0.77
*The negative correlation of vulnerability to % housing units that are mobile homes is contrary to my assumptions, especially when I consider memories of the aftermath of trailer parks following a tornado or hurricane. From the authors' notes, this variable appears to speak for the differences in population density of urban and rural areas, with urban areas (fewer mobile homes) having the potential for greater gross level of displaced residents.				
Sources: Cutter, Boruff, & Shirley, 2003, p. 252				

Table 5: Susan Cutter's Dimensions of Social Vulnerability

A team of researchers from the National Center for Environmental Health and the Indiana University Institute for Research on Social Issues built the Extreme Heat Vulnerability Index (EHVI) in 2012. While the authors only tested their Extreme Heat Vulnerability Index methodology on a single case study (Chicago's Heat Wave of 1995), the authors selected indicators based on prior hazard and vulnerability research. The author's nineteen selected indicators explained 79.41% of the variance in levels of social vulnerability at the Census block group level (see Table 6 on page 47) (Johnson, Stanforth, Lulla, & Luber, 2012, p. 25). These indicators outperformed three alternative measures of risk during extreme heat events: population density (urban heat island effect), socioeconomic risk (traditional vulnerability), and land surface temperature (Johnson, Stanforth, Lulla, & Luber, 2012). The authors believe the Extreme Heat Vulnerability Index is "primed for implementation and testing" and localities can immediately begin using the index for decision making prior to and during extreme heat events (Johnson, Stanforth, Lulla, & Luber, 2012, p. 29). Potential applications of the Extreme Heat Vulnerability Index include placement of emergency cooling centers, locating additional medical transportation and increasing medical center staffing in highly vulnerable areas, and improved targeting of urban heat island mitigation (Johnson, Stanforth, Lulla, & Luber, 2012, p. 29).

Explanatory Variables for Extreme Heat Vulnerability Index
Females age 65 and up
Males age 65 and up
Females age 65 and up living alone
White population
Females head of household
Males age 65 and up living alone
Mean family income
Per capita income
Mean household income
Population 25 and older with less than high school education
Asian population
Population age 65 and older in group living
Other race population
Hispanic population
Population 25 and holder with a high school education
Normalized difference built-up index (density)
Normalized difference vegetation index
Black population
Land surface temperature
Source: (Johnson, Stanforth, Lulla, & Luber, 2012, p. 25)

Table 6: Explanatory Variables for Extreme Heat Vulnerability Index

The Centers for Disease Control and Prevention developed a Social Vulnerability Index (SVI) to encourage emergency management professionals to integrate social vulnerability into hazard mitigation and response documents. The Social Vulnerability Index is mapped at the Census tract scale (as opposed to Cutter's county-level scale) in order to more accurately identify the location of vulnerable population groups while maintaining access to nationally collected data (i.e., Decennial Census and the American Community Survey) (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011, p. 4). The fifteen variables of vulnerability selected for the Social Vulnerability Index (see Table 7 below) were chosen based upon consensus in public health and hazard research literature.

Variables Used to Compute the Centers for Disease Control and Prevention Social Vulnerability Index (2014)														
Overall Vulnerability														
Socioeconomic Status				Household Composition & Disability				Minority Status & Language		Housing & Transportation				
Below poverty	Unemployed	Income	No high school diploma	Aged 65 or older	Aged 17 or younger	Civilian with a disability	Single-parent household	Minority	Speak English "less than well"	Multi-unit structures	Mobile homes	Crowding	No vehicle	Group Quarters
Source: Centers for Disease Control and Prevention, 2017a														

Table 7: Variables used to compute the Centers for Disease Control and Prevention's 2014 Social Vulnerability Index

2.6.B – Locating Socially Vulnerable Places

vulnerability indices can be mapped to provide a visual representation of where the most vulnerable populations live. The visual representation can be used by planners to guide hazard mitigation efforts or to identify vulnerable populations for education and research efforts. For example, a group of researchers identified Marylanders located in urban heat islands or floodplains to survey the residents on their perceived health risks as a result of global climate change (Akerlof, Delamater, Boules, Upperman, & Mitchell, 2015).Social

Cutter's Social Vulnerability Index (SoVI) relies upon county-level Census data. While this level of detail is not appropriate for a local multi-hazard mitigation plan, the method displays the usefulness and ability of mapping social vulnerability. Previously generated state maps of county-level social vulnerability using Cutter's Index (see Figure 12 below) are available through the University of South Carolina's Hazard and Vulnerability Research Institute at https://artsandsciences.sc.edu/geog/hvri/sovi®-0.

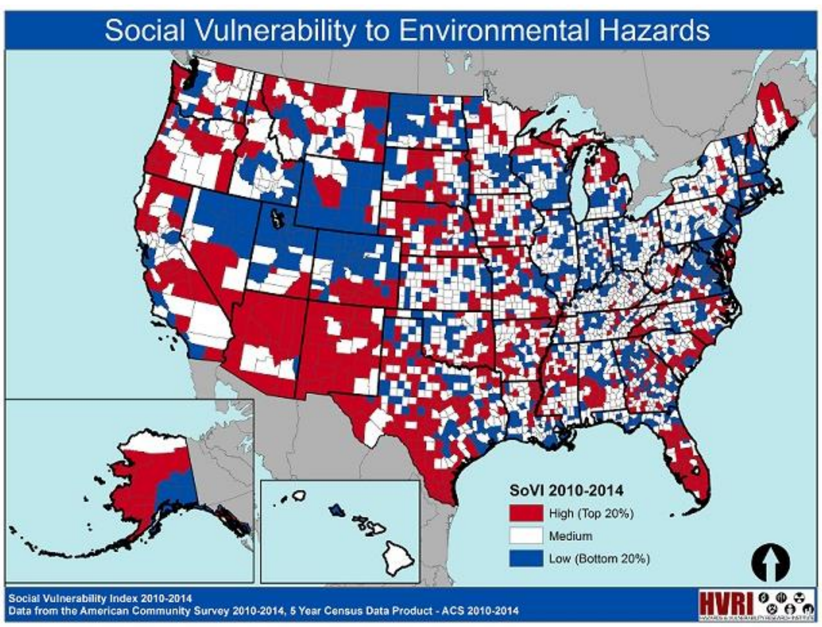

Figure 12: Map of Cutter's Social Vulnerability Index using county-level Census data. (Hazards & Vulnerability Research Institute, n.d.)

Another example of mapping social vulnerability is the United States' Centers for Disease Control and Prevention (CDC) in-house Social Vulnerability Index (SVI). Their methodology better suits local planners by utilizing Census tract-level data (Agency for Toxic Substances and Disease Registry, n.d.). Separately, the CDC built an interactive mapping dashboard that allows planners to explore and reorganize the Social Vulnerability Index in pre-made maps at the state, county, ZIP code, and Census tract levels. Figure 13 (below) shows the CDC's 2014 Social Vulnerability Index map for Rhode Island at the Census tract level. This interactive mapping dashboard is available at https://svi.cdc.gov/map.aspx.

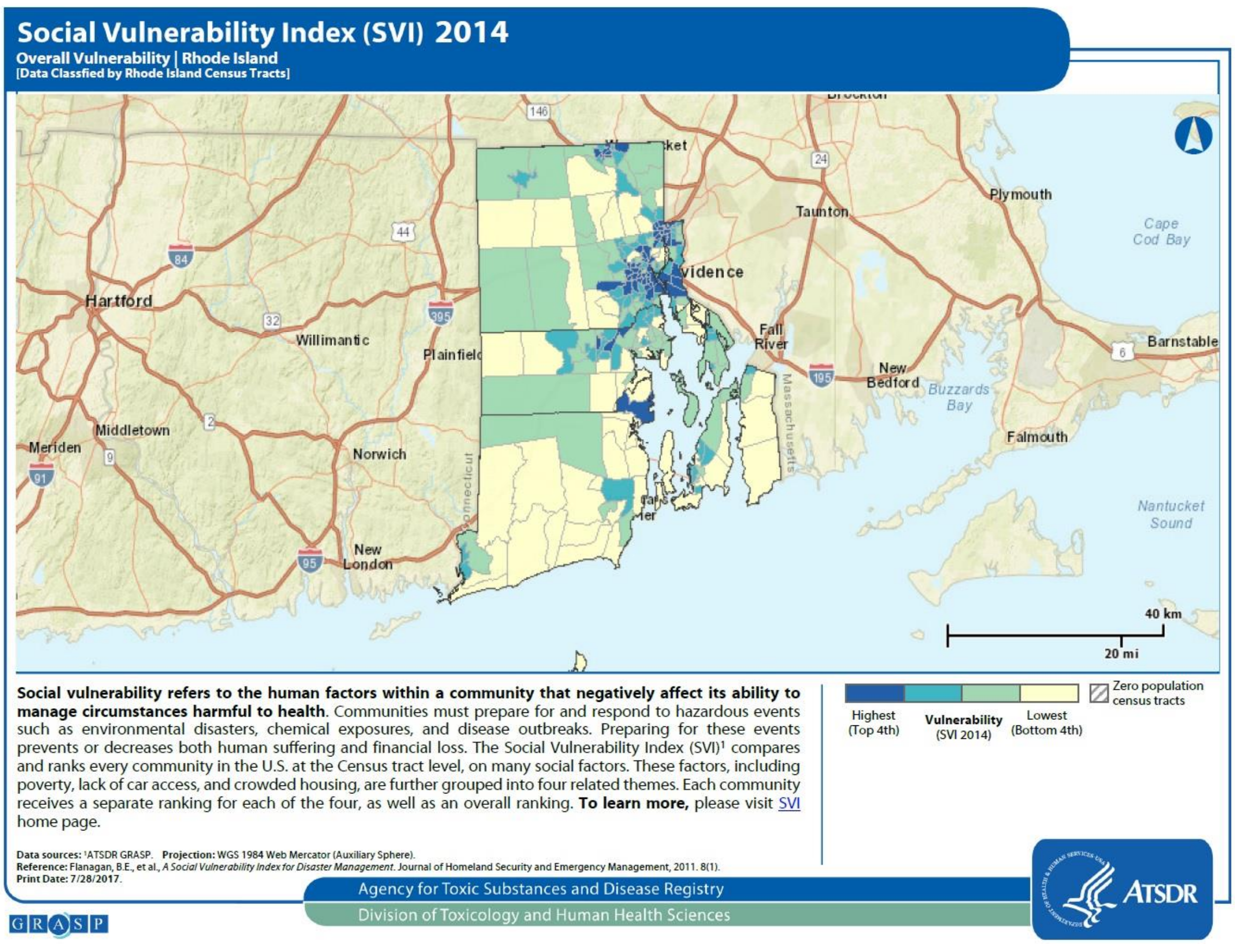

Figure 13: Map of Rhode Island's social vulnerability using the CDC's Social Vulnerability Index mapping tool.

(Agency for Toxic Substances & Disease Registry, 2014)

2.6.C –Extreme Heat Events and Human Health

All heat-related illnesses are preventable (Centers for Disease Control and Prevention, 2017d). While humans can acclimatize ("physiologically adjust to an environment") to heat, we have a limited biological ability to acclimatize to heat (Wenger, 2002, p. 52 & 79; Hanna & Tait, 2015, p. 8055). Given the length of evolutionary time frames and the increases in global temperatures and duration, intensity, and frequency of extreme heat events, it is unlikely that humans will be able to acclimatize to future heat (Hanna & Tait, 2015, p. 8039). Therefore, identification of vulnerable populations is essential because extreme heat events pose an unnecessary threat to quality of life and reduces community life expectancy.

Building upon the previous section on social vulnerability, there is a subset of vulnerable populations most likely to experience decreased quality of life or premature mortality during an extreme heat event. These include adults over the age of 65—especially those who live alone—as well as infants and children, outdoor workers and athletes, people with chronic medical conditions, people experiencing homelessness, and members of low-income households (Water, Air and Climate Bureau Healthy Environments and Consumer Safety Branch, 2011, p. 19; Centers for Disease Control and Prevention, 2017c).

Pre-existing conditions can potentially be aggravated during extreme heat events. People who are overweight or obese, diabetic, asthmatic, or suffer from cardiovascular disease face an increased risk of health complications (Centers for Disease Control and Prevention, 2017b, p. 2).

Acclimatization to extreme heat, or thermotolerance, refers to the body's ability to withstand heat stress (Hanna & Tait, 2015, p. 8039). Developing thermotolerance requires time or effort to acclimate then additional time or effort to maintain resistance to extreme heat. General global warming combined with more intense extreme heat events—both effects of climate change—will further limit the human body's ability to maintain healthy core body temperatures (Hanna & Tait, 2015; p. 8056). Office workers, the un/underemployed, and tourists may not be able to develop sufficient thermotolerance, especially in the future experiencing the consequences of unabated climate change (Hanna & Tait, 2015, p. 8057).

The body's inability to further cope with extreme heat results in heat-related illnesses. When the body is no longer able to sufficiently dissipate body heat in relation to the body's heat gain—whether from environmental factors or physical exertion—a person will begin to exhibit the effects of heat-related illnesses (Wegner, 2002, p.52). Although medical science has a well-researched and well-documented knowledge base on heat-related illnesses, the public's lack of awareness and misconceptions impair the ability of people to diagnose and take proactive and reaction actions to prevent and protect themselves and others from experiencing heat-related illnesses. People should be aware of the three primary heat-related illnesses, the common symptoms, and potential health outcomes.

Heat-related illnesses listed by escalating risk of mortality:

1) Heat Cramps

Heat cramps may be the first sign that a person is developing a life-threatening heat-related illness (Centers for Disease Control and Prevention, 2017d). Heat cramps are likely caused by dehydration or electrolyte imbalances. The common symptoms of heat cramps are heavy sweating combined with painful muscle cramps and/or spasms in the legs, arms, or abdomen (Centers for Disease Control and Prevention, 2017d; Korey Stringer Institute, 2017a).

2) *Heat Exhaustion*

Heat exhaustion is the most common heat-related illness (Korey Stringer Institute, 2017b). It is medically defined as a body temperature of 104°F and may require emergency medical treatment to prevent death (University of Pittsburgh Medical Center, 2016). Extreme heat events pose a health threat because exposure to extreme heat over an extended period is an aggravating factor for heat exhaustion (U.S. Environmental Protection Agency & Centers for Disease Control and Prevention, 2016, p. 9).

3) *Heat Stroke*

Heat stroke requires immediate medical attention. Heat stroke is medically defined as a body temperature greater than or equal to 105°F. Although heat strokes are often an escalation of untreated heat exhaustion, a victim does not necessarily exhibit the symptoms of heat exhaustion before exhibiting the symptoms of heat stroke (University of Pittsburgh Medical Center, 2016; Korey Stringer Institute, 2017b).

The National Weather Service and the Sacramento Office of Emergency Services have created a helpful public information poster that identifies symptoms of heat exhaustion and heat stroke along with the recommended course of action (see Figure 14 on page 54). The Centers for Disease Control and Prevention created the *Beat the Heat* infographic to provide communities an easy-to-understand poster that explains the basics of extreme heat events to the public (see Figure 15 on page 55).

Figure 14: Example of an easy to understand graphic explaining the difference between heat exhaustion and heat stroke
(National Weather Service & Sacramento Office of Emergency Services, n.d.)

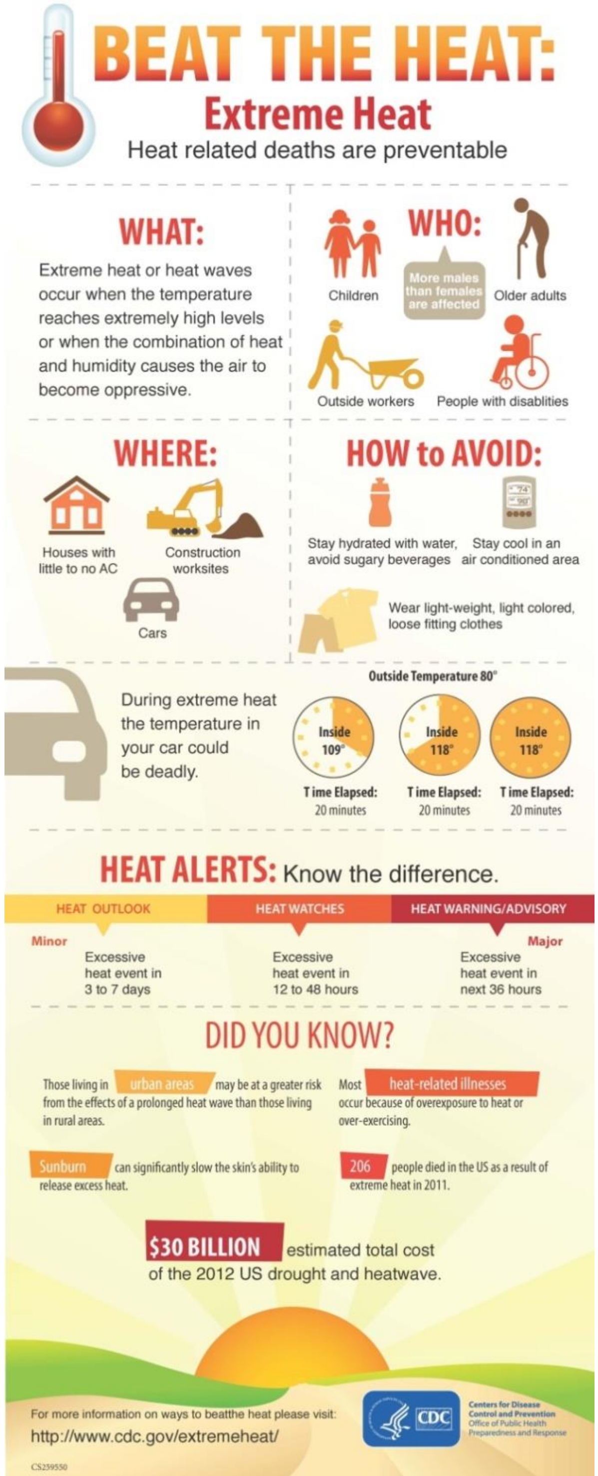

Figure 15: Centers for Disease Control and Prevention extreme heat event informational poster geared towards the public
(Centers for Disease Control and Prevention, 2013)

2.7 – Chapter Summary

Extreme heat events have long traumatized humans. This is unlikely to change in the future because our actions (i.e., human-induced climate change) will amplify the intensity, lengthen the duration, and increase the frequency of extreme heat events. As local stakeholders, political leaders, and community planners, we need to develop better hazard mitigation plans that adequately address the threats to human life posed by extreme heat events. From the literature on extreme heat events, I identified four key lessons for addressing community risk to extreme heat events:

1) Extreme heat events are deadly. Know the history of extreme heat events for your community. This knowledge allows you to understand how people have historically reacted to this common disasters, identify potential gaps in local knowledge, highlight prior breakdowns in social services during events, and establish more effective public outreach efforts.
2) Understand how human-induced climate change and the current arrangement of the built environment augment the threat posed by extreme heat events. Disaster planning is no longer solely the realm of emergency management and their response following hazard events. Planners must enter the conversation during the mitigation and preparedness phases to decrease the risk posed by future hazard events.
3) Transparently define extreme heat events for your community. Defining extreme heat events has posed a challenge for researchers because extreme heat differs from region to region, and person to person. A transparent, documented process allows continuous debate and conversation within the community on the values

and needs of the community, especially when analyzing the plan's successes and failures following the next extreme heat event.

4) Social vulnerability must play a prominent role in developing extreme heat event hazard mitigation plans. The tools and indices needed to identify and integrate social vulnerability into hazard mitigation plans already exist. Therefore, a lack of social vulnerability integration into hazard mitigation plans represents a failed process.

These four lessons will serve as guideposts in analyzing extreme heat event-related planning documents in chapter 3. While I will only apply these lessons to my analysis of the City of Baltimore's documents, any stakeholder can use the guideposts to critique their community's extreme heat event planning documents.

Chapter 3 – Case Study: City of Baltimore, Maryland

In this chapter I use a case study of Baltimore, Maryland, to apply the knowledge from the literature review to demonstrate how the information can immediately improve planning for extreme heat events. This case study begins by reviewing all readily available public documents that cover hazards or related topics. I include only readily available public documents since most residents—the target group for hazard risk reduction—lack the time, awareness, or sophistication to request unavailable documents. After summarizing the extreme heat event-related material in each document, I will discuss the information through a compressed version of my literature review workflow (see Figure 16 below).

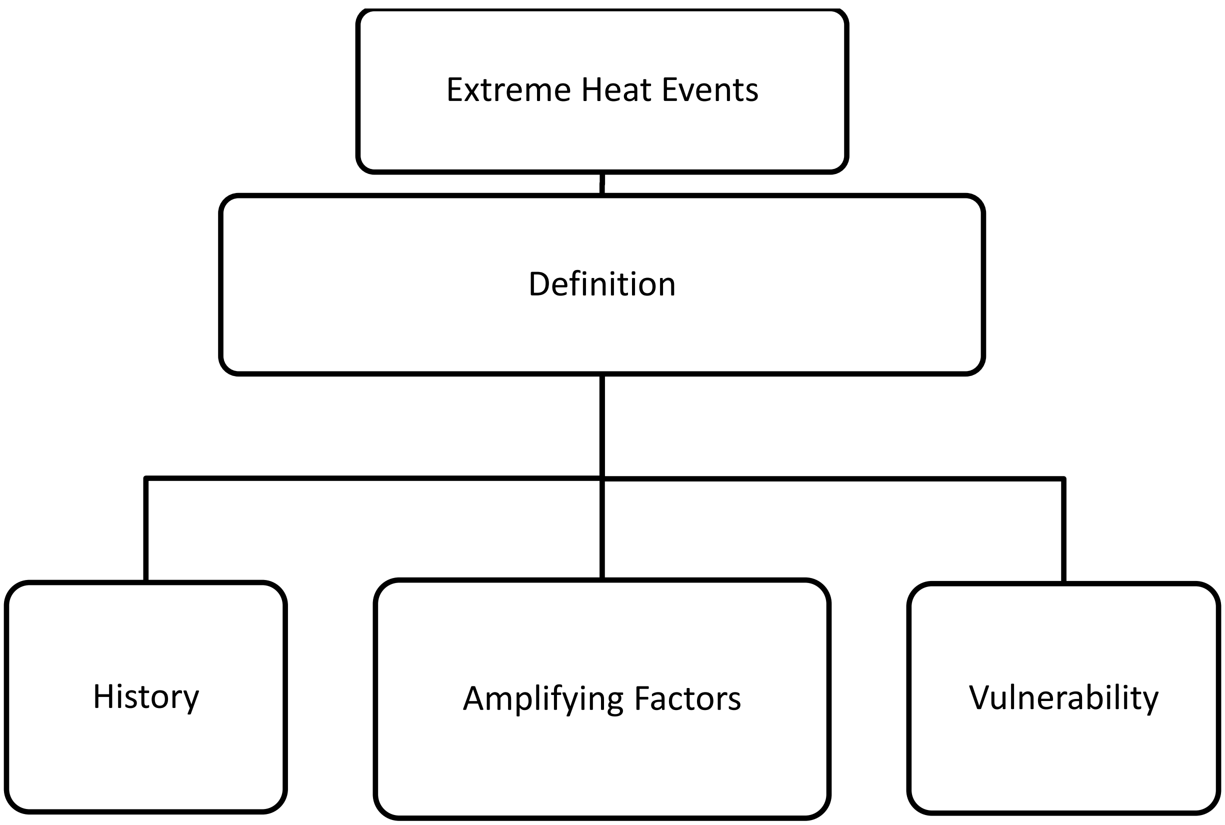

Figure 16: Compressed Literature Review Workflow for Case Study Discussion (Andrew Asgarali-Hoffman, 2017)

3.1 – City of Baltimore Extreme Heat Event-Related Documents

I identified five documents that provide insight into Baltimore's extreme heat event planning efforts. I will review Baltimore's 2006 and 2013 multi-hazard mitigation plans, 2009 Sustainability Plan, 2012 Climate Action Plan, and the annual Code Red Heat Warning plan.

3.1.A – All-Hazards Plan (2006)

Baltimore's 2006 All-Hazards Plan identifies extreme heat events as a hazard that "may significantly affect Baltimore City" (City of Baltimore Department of Planning, 2006, p. 5). Since extreme heat events are a potential hazard for Baltimore, the planners produced a risk profile, vulnerability assessment, and mitigation strategies for the hazards for extreme heat events.

In the risk profile, the authors anecdotally state that Baltimore summers "are known for their frequent high temperatures accompanied by high humidity" and explain how the urban heat island effect increases "urban air" temperatures (City of Baltimore Department of Planning, 2006, p. 19). The authors note that there are Baltimoreans "who cannot afford to air condition their homes or choose not to do so" even though "Baltimore's prototype row house can become extremely hot during times of 90+ degree days and nights" (City of Baltimore Department of Planning, 2006, p. 19). The profile concludes "that extreme heat is a significant hazard in Baltimore" because "nearly every summer Baltimore has an extreme heat event" (City of Baltimore Department of Planning, 2006, p. 19).

The brief vulnerability assessment identifies human costs as the primary cost of extreme heat events. The authors state that "elderly residents in rowhouse neighborhoods with little tree cover are most likely to suffer" (City of Baltimore Department of Planning, 2006, p. 35). The authors then provide a list of the ten neighborhoods with the lowest percentage of tree cover and the corresponding gross number of neighborhood residents at least 65 years old.

Baltimore's All-Hazards Plan identifies four broad hazard mitigation goals (City of Baltimore Department of Planning, 2006, p. 37):

- Protecting the health and safety of Baltimore City residents and visitors.
- Preventing damage to structures, infrastructure, and critical facilities.
- Developing a public understanding about the effects of hazards and the need for mitigation.
- Integrating disaster prevention into complementary City initiatives.

These mitigation goals were used to inform the development of hazard mitigation strategies and actions (see Table 8 on page 61). Documents highlighting the results of the monitoring and evaluation of the All Hazards Plan are not readily available to the public.

Baltimore's 2006 All-Hazards Plan Mitigation Strategies and Actions	
Strategy	**Extreme Heat Action**
Develop up-to-date research about hazards	none
Maintain City infrastructure and improve operations	none
Enhance and protect City's natural assets where such assets can aid hazard mitigation objectives	Set appropriate tree canopy goals for major land uses throughout Baltimore; expand tree planning program to provide tree cover in central Baltimore neighborhoods. Adjust policies on the size of tree pits in sidewalks to allow for better establishment and growth of street trees.
Development programs, regulations, and codes that integrate disaster prevention	Develop landscape ordinance to "green" Baltimore and provide parameters for healthy maintenance of vegetation.
Prevent damage to existing structures	Revise existing rowhouse redevelopment manual to provide advice about shoring up roofs to withstand snow loads and high winds, building green roofs, and using white or reflective paint or other material to reflect heat.
Educate residents about the existence of hazards, mitigation programs, and incentives.	Develop an outreach program to inform low-income and seniors about the existence of weatherization and energy assistance programs. Post emergency planning tips on the Baltimore City website to educate the public on the proper course of action in the event of a severe weather event
Provide direct assistance to low-income individuals, seniors, and others who need it.	Distribute fans to seniors and low-income households.
Source: Andrew Asgarali-Hoffman, 2017, adapted from City of Baltimore Department of Planning, 2006	

Table 8: Baltimore's 2006 All-Hazards Plan Mitigation Objectives and Extreme Heat Event Strategies

3.1.B – DP3 Multi-Hazard Mitigation Plan (2013)

Baltimore's Disaster Preparedness and Planning Project (DP3) is the city's FEMA approved multi-hazard mitigation plan. This plan was formally adopted in October 2013. The 2013 plan is in-depth, comprehensive, and noticeably longer plan than the 2006 plan.

The Extreme Heat Hazard Assessment opens by defining extreme heat events as a period of "prolonged temperatures…10° or more above the average high temperature for the region" (Baltimore Office of Sustainability, 2013, p. 84). This definition is not placed into context through the inclusion of average high temperatures for Baltimore nor is the definition source provided. The authors move the discussion to the history of extreme heat events in Baltimore. The authors review the annual average number of extreme heat events, the projected number of extreme heat events given the amplifying effects of climate change, and the lengthiest extreme heat events to impact Baltimore. The authors also developed a time series graph depicting individual extreme heat events as a value of the number of degrees above 97°F for the events average high temperature (Baltimore Office of Sustainability, 2013, p. 87). No reference for the source of information is provided. The 2013 multi-hazard mitigation plan builds upon the knowledge established in the 2006 All-Hazards Plan on the urban heat island effect by including imagery depicting Baltimore's developed land and land surface temperatures (Baltimore Office of Sustainability, 2013, p. 85). The Extreme Heat Hazard Assessment concludes by identifying the health risks (heat stress, heat exhaustion, and heat stroke) associated with extreme heat events and populations at greater risk of being affected (the elderly, young children, and people with respiratory difficulties) (Baltimore Office of Sustainability, 2013, p. 86).

The DP3 Vulnerability Assessment describes—but does not detail—a Societal Impact Analysis that can be utilized to identify persons, places, and activities which face increased risk to hazard events (Baltimore Office of Sustainability, 2013, p. 108). The Extreme Heat Vulnerability Assessment prioritizes the extreme heat risks faced by places (parks and tree canopy) and activities (critical infrastructure) (Baltimore Office of Sustainability, 2013, p. 142-144). Although an elderly woman suffering from intense heat is pictured in this section, minimal attention is paid to the human risks of extreme heat events.

Baltimore's DP3 Plan identifies six broad hazard mitigation goals (Baltimore Office of Sustainability, 2013, p. 152):

- Protecting the health and safety of Baltimore City residents and visitors.
- Preventing damage to structures, infrastructure, and critical facilities.
- Building resilience and disaster prevention and planning into all programs, policies, and infrastructure (public and private).
- Enhancing the City of Baltimore's adaptive capacity and building institutional structures that can cope with future conditions that are beyond past experience.
- Promoting hazard mitigation and climate adaptation awareness and education throughout the City of Baltimore.
- Becoming a Community Rating System (CRS) classified community.

These mitigation goals were used to inform the development of hazard mitigation objectives and strategies (see Table 9 on page 65). Documents highlighting the results of the monitoring and evaluation of the All Hazards Plan are not readily available to the public.

Unlike the brief 2006 All-Hazards Plan with seven mitigation strategies, the 2013 DP3 Multi-Hazard Mitigation Plan incorporates fifty strategies, each with numerous actions, spread amongst four sectors: Infrastructure, Buildings, Natural Systems, and Public Services. While extreme heat event mitigation actions are located across four sectors, most extreme heat event mitigation actions are located in Natural Systems and Public Services. The DP3 Multi-Hazard Mitigation Plan hazard mitigation actions related to extreme heat events are presented in table 9 on page 65.

Baltimore's DP3 Multi-Hazard Mitigation Plan's (2013) Extreme Heat Event-Related Hazard Mitigation Strategies and Actions		
Sector	**Strategy**	**Action**
Infrastructure	IN-7: Integrate climate change into transportation design, building, and maintenance.	Design bridge expansion joints for longer periods of high heat and develop a more robust inspection and maintenance process
Infrastructure	IN-11: Evaluate changes to road maintenance and construction materials based on anticipated changes in climate	Implement a repaving strategy that reduces heat-related damage to asphalt and incorporates maintenance and operations that extend the life of the road surface
Infrastructure	IN-11: Evaluate changes to road maintenance and construction materials based on anticipated changes in climate	Design pavement sections and materials that withstand longer periods of extreme heat events
Infrastructure	IN-15: Conduct an assessment that evaluates and improves all pipes' ability to withstand extreme heat and cold	
Buildings	BL-2: Enhance City building codes that regulate building within a floodplain or near the waterfront	Encourage green roof installations to include vegetated and reflective technologies for all new commercial, industrial, multifamily, and city-owned development
Natural Systems	NS-2: Increase and enhance the resilience and health of Baltimore's urban forest	Increase the urban tree canopy and target areas with urban heat island impacts
Natural Systems	NS-3: Create an interconnected network of green spaces to support biodiversity and watershed based water quality management	Utilize the Growing Green Initiative to increase green spaces in areas where there is available vacant land in order to reduce the heat island effect
Natural Systems	NS-3: Create an interconnected network of green spaces to support biodiversity and watershed based water quality management	Create a strategic plan that identifies areas of focus for tree planting, stormwater management, and forest preservation.
Public Services	PS-2 Develop a Hazard Awareness Program	Create a standardized early warning system for members of the public
Public Services	PS-2 Develop a Hazard Awareness Program	Educate citizens about the existing early warning systems and actions they should take when alarms sound
Public Services	PS-7: Protect Baltimore residents from the effects of hazard events and plan for more frequent hazard instances	Re-evaluate and update existing heat alerts, advisories, and updates to healthcare and emergency service providers
Public Services	PS-7: Protect Baltimore residents from the effects of hazard events and plan for more frequent hazard instances	Ensure that residents and visitors have access and transportation to cooling centers during extreme heat events
Source: Andrew Asgarali-Hoffman, 2017, adapted from Baltimore Office of Sustainability, 2013		

Table 9: Baltimore's DP3 Multi-Hazard Mitigation Plan's (2013) Extreme Heat Event-Related Hazard Mitigation Strategies and Actions

3.1.C – Sustainability Plan (2009)

Baltimore's 2009 Sustainability Plan was crafted as both an addendum to the City's 2006 Comprehensive Plan and a standalone plan (Baltimore Office of Sustainability, n.d.). The Sustainability Plan is organized into seven core themes: cleanliness; pollution prevention; resource conservation; greening; transportation; environmental education and awareness; and the Green Economy. Any effort to curb the City's contribution to factors causing climate change will reduce, regardless of magnitude, the risk posed by extreme heat events. The Sustainability Plan seeks to identify "how Baltimore can grow and prosper in ways that meet the current environmental, social and economic needs of [the] community" (Baltimore Office of Sustainability, 2009). Climate change plays a central role in motivating the creation and organization of the document. However, the plan does not directly address the threats posed by hazard events and does not mention extreme heat events. The Sustainability Plan's core theme of "Greening" does address urban heat island effect mitigation. The authors note that increasing tree canopy coverage will provide shade, reduce the urban heat island effect, and reduce summertime reliance on air conditioning (Baltimore Office of Sustainability, 2009).

A goal of the Greening theme is doubling Baltimore's tree canopy coverage by 2037. This goal consists of seven strategies (Baltimore Office of Sustainability, 2009, p. 71-73):

1) Assess current urban forest cover
2) Protect existing trees
3) Build communication and cooperation among city agencies to support Baltimore's trees
4) Develop a city-wide education program about the value of trees
5) Develop and strengthen innovative public-private partnerships
6) Identify and pursue opportunities for increasing trees planted on private property

7) Increase tree plantings in sidewalks, medians, and other public right-of-ways

3.1.D – Climate Action Plan (2012)

The Baltimore Sustainability Plan acts as a complement to Baltimore's 2006 comprehensive master plan and an extension of the Pollution Prevention core theme of the Sustainability Plan. The first sentence of the Sustainability Plan's executive summary states that "increased temperatures" and "more extreme heat days" are climate change threats faced by the City of Baltimore (Baltimore Office of Sustainability, 2013, p. 4). While the document is centered on reducing Baltimore's greenhouse gas emissions to combat climate change, the plan also strategizes mitigation actions to combat the effects of climate change on Baltimoreans. While Greenhouse Gas Reduction Measures include some strategies that could affect the risk posed by extreme heat events (e.g., increased energy efficiency, updating building code, increase tree canopy coverage), the Climate Adaptation chapter is where the authors address the threat of extreme heat events.

Addressing the projected threat of increased frequency, intensity, and duration of extreme heat events, the authors state that Baltimore issues a "Code Red Heat Alert…with a 95°F temperature" (Baltimore Office of Sustainability, 2013, p. 65). Code Red Heat Alerts trigger the opening of Baltimore's cooling centers (see section 3.1.E – Baltimore City's Code Red Heat Alert Plan, pages 70-71, for more information). Geographic information systems data can provide planners the ability to "focus adaptation strategies on those most at risk" (Baltimore Office of Sustainability, 2013, p. 69). The Climate Action Plan focuses extreme heat event risk on the existing tree canopy, the urban heat island effect, and location of elderly residents. The idea of using geographic information systems to identify extreme heat event vulnerability is an example of potential adaptation planning.

Listed below are the Climate Action Plan's Adaptation Priorities that I identified as directly or indirectly mentioning extreme heat events (Baltimore Office of Sustainability, 2013, p. 70-71).

1) Assess potential health threats and the sufficiency of Baltimore's response capacity, including:
    a. Improve the clarity, granularity, and availability of health and population data
    b. Analyze health and population data along with other information (e.g., land use, air quality, water quality)
    c. Assess vulnerability of the elderly and young to extreme weather events, particularly heat waves, and identify where those populations are (building on the Code Red Heat Alert Plan and Response
2) Integrate climate adaptation into planning processes (to start in the All Hazards Mitigation Plan update)
    a. Integrate adaptation strategies into energy and other building and zoning codes (designing for longer hotter summers, etc.)
    b. Expand the amount of open, vegetated and wetland spaces in the city to improve the long-term health of the tree canopy, forests and meadowlands by providing relief from heat island effect
3) Develop a communications plan
    a. Develop a communications plan and implement activities such as workshops, webinars, and electronic activities to increase the awareness of city management and front-line city staff about the local impacts of climate change and adaptation
    b. Develop a public communications strategy regarding existing and future risks, particularly in relation to property and public health.

3.1.E – Baltimore City's Code Red Heat Alert Plan

The Mayor's Office of Emergency Management states that, "Every year, before the onset of hot weather, the City works to update and implement its Code Red Heat Alert Plan" (Mayor's Office of Emergency Management, 2016). Baltimore's Health Commissioner "declares a Code Red Heat Alert day during period of extreme heat" (Mayor's Office of Emergency Management, 2016). Alarmingly, the Code Red Heat Alert Plan is not publicly available. Information on the Code Red Heat Alert Plan can be gathered from the Baltimore Mayor's Office of Emergency Management, the Baltimore City Health Department, and a 2016 journal paper written by Jennifer Martin, who at the time was the Director of the Baltimore City Health Department's Office of Public Health Preparedness and Response.

The responsibility to declare a Code Red Heat Alert rests upon the City's Health Commissioner. Publicly, the Mayor's Office of Emergency Management web page states that Code Red Heat Alert days are declared "during periods of extreme heat" (Mayor's Office of Emergency Management, 2016). The Baltimore City Health Department adds that this decision "will be made before 6 A.M. of that day, if possible" (Baltimore City Health Department, 2017). The journal article, which lies behind a paywall, further clarifies that the Health Commissioner will declare a Code Red Heat Alert "when the heat index is forecast to be 105° or greater" (Martin, 2016, p. 72).

A Code Red Heat Alert declaration opens eleven community cooling centers throughout the city (Baltimore City Health Department, 2017; Martin, 2016). These cooling centers are open from 8:30 A.M. to 4:30 P.M. on weekdays and from 11:00 A.M. to 7:00 P.M. on weekends (Baltimore City Health Department, 2017). Homeless outreach teams and the Salvation Army attempt to contact homeless individuals and distribute bottled water (Martin, 2016, p. 72). To better publicize the Code Red Heat Alert, the Baltimore City Health Department organizes press conferences and writes official press releases for local news agencies to report, places Reverse 911 calls to city residents, conducts door-to-door outreach by emergency responders, and uses social media as an outreach tool (Martin, 2016, p. 73).

3.2 – Discussion on Baltimore's Extreme Heat Event Hazard Planning Products

Even though Baltimore City's DP3 multi-hazard mitigation plan is considered an exemplary plan by the authors behind the *Beyond the Basics* hazard mitigation research project, the case study in this paper should raise awareness on potential shortcomings of even the best plans. Baltimore has spread out its extreme heat event hazard mitigation efforts across five independent documents: the 2006 Comprehensive Plan, the 2013 DP3 multi-hazard mitigation plan, the 2009 Sustainability Plan, the 20012 Climate Action Plan, and the annual Code Red Heat Alert plan. While these plans refer to each other, these plans are either out-of-date, approaching expiration, or impossible to locate.

However, I intend for this professional report to be useful to planners beginning a rewrite (or first write) of their community's multi-hazard mitigation plan. This case study is intended as an example of how to determine how past planning documents—in this case, five documents from the City of Baltimore—address key areas of extreme heat events. Table 10 on page 73 is a matrix comparing each planning document to the six key areas of the literature review: community-centric extreme heat event definition; history of local extreme heat events; climate change's relation to extreme heat events; the urban heat island effect; social vulnerability; and health effects of extreme heat events.

Extreme Heat Event-Related Documents and Topics Identified in Literature Review					
	All-Hazards Plan (2006)	**Sustainability Plan (2009)**	**Climate Action Plan (2012)**	**DP3 Multi-Hazard Mitigation Plan (2013)**	**Code Red Heat Alert Plan**
Baltimore-centric Extreme Heat Event Definition	No	No	No	No—definition of "10° or more above average high temperatures" is provided without context	No—choice of a 95°F threshold lacks explanation
History of Extreme Heat Events in Baltimore	No	No	No	Yes	No
Climate Change's Relation to Extreme Heat Events	No	No	Yes	Yes	No
Urban Heat Island Effect Discussion	Yes	Yes	Yes	Yes	No
Social Vulnerability Analysis	Yes—*one sentence states "elderly residents in rowhouse neighborhoods with little tree cover are most likely to suffer."*	No	Yes	Yes	Indirectly—*journal paper by City employee speaks directly about who is socially vulnerable*
Health-effects of Extreme Heat Events	Yes—*one sentence states "costs of extreme heat are primarily human."*	No	No	Yes	Yes
Source: Andrew Asgarali-Hoffman, 2017					

Table 10: Comparison of Extreme Heat Event-Related Documents to Topics Identified in Literature Review

Both hazard mitigation plans along with the Sustainability Plan and Climate Action Plan develop a complete roadmap for how Baltimore plans to combat the urban heat island effect through the planned use of improved building codes, mandates and incentives, and a redeveloped urban tree canopy. The City does not appear to have kept its promise of monitoring and evaluating the growth of Baltimore's urban tree canopy. TreeBaltimore, the public-private partnership charged with coordinating the canopy's growth, does not appear to maintain an updated website and the Tree Canopy map has not been updated since 2007 (TreeBaltimore, 2014). The best-laid plans are ineffective if we never review their implementation.

The two most recent documents—the Climate Action Plan and the DP3 Multi-Hazard Mitigation Plan—both prominently feature climate change as a direct threat to the livelihood of Baltimore and its residents. This should remain constant in future updates of the plan even with Donald Trump withdrawing the United States from the Paris Climate Accord. The Baltimore City Council voted to uphold the Paris Climate Accord on June 19th, 2017 (WJZ-TV CBS Baltimore, 2017).

While Baltimore's planners have progressively increased the comprehensiveness of each hazard-related planning document, there are significant gaps that raise red flags concerning Baltimore's ability to respond to extreme heat events effectively. None of the five documents included a Baltimore-centric extreme heat event definition. The Code Red Heat Alert Plan—which is not readily accessible to the public—and the DP3 Multi-Hazard Mitigation Plan define extreme heat events. The definitions are not consistent between plans and the reasoning for the selection of the thresholds is not provided. Additionally, whether or not the planners considered the duration of an extreme heat event while choosing a definition is not known. While a best practice for crafting a local definition is not established, transparency of the decision-making process allows for discussion and dissent in determining public's business (Veal, Sauser, Tamblyn, Sauser, & Sims, 2015, p. 11)

Another incongruity appeared with the Code Red terminology. Baltimore City's Code Red extreme heat event days are different from the Code Red designation in The Baltimore Sustainability Plan. The Sustainability Plan's Code Red designations reference the United States' Environmental Protection Agency's Air Quality Index (AQI). The AQI's Code Red designates an unhealthy air quality for everyone with people of air quality sensitive groups potentially experiencing serious health effects (U.S. EPA Office of Air Quality Planning and Standards, 2016). With the DP3 Multi-Hazard Mitigation Plan seeking to create a uniform early warning system, a single term with multiple potential meanings may not be the best choice. This case highlights the importance of choosing and defining terms.

The most worrying aspect of Baltimore's extreme heat event planning efforts is the lack of attention paid to social vulnerability. There is a generally negative reaction to Baltimore (Sauter, Stebbins, & Comen, 2017; Bernardo, 2017). Popular culture portrays Baltimore as a violent, poor city. While I believe these assumptions often stem from the United States' ingrained white racial frame and pop culture (e.g., *The Wire*), the root assumption that Baltimore has problems is not wrong. Baltimore is a highly inequitable city. Wealth and poverty are highly concentrated at the neighborhood level (Berube & McDearman, 2016). Neighborhoods are largely segregated by race (Berube & McDearman, 2016). Eight Baltimore neighborhoods had lower life expectancies in 2015 than war-ravaged Syria (Ingraham, 2015). The average poor, black Baltimorean is sicker and weaker than the average Marylander, and more likely to die at a young age (Perman, 2016). Social vulnerability emerged in the hazard mitigation literature since the 1990s. The vulnerability of Baltimore's residents is a studied topic, and it is not a secret.

Social vulnerability emerged in the hazard mitigation literature since the 1990s. With social inequity an important national topic since the mid-2000s, it is a moral wrong that Baltimore's planners have not incorporated social vulnerability language into the City's recent planning documents.

The plans analyzed in this chapter are approaching the end of their life cycles. Baltimore's DP3 Multi-Hazard Mitigation Plan expires in 2018—the fifth year of its FEMA approval cycle. Baltimore's comprehensive plan, first adopted in 2006, is no longer valid under Maryland's required ten-year review and update cycle (Maryland Department of Planning, n.d.). When Baltimore adopted its comprehensive plan, the state required review and updates every six years (Maryland Department of Planning, n.d.). The City's Planning department is currently updating the Sustainability Plan. Baltimore's planners, leaders, and stakeholders must take a step back and determine if independently developing these plans and loosely connect them in brief one-page write ups (see page 14 in Baltimore's DP3 Multi-Hazard Mitigation Plan and page 8-9 in Baltimore's Climate Action Plan) is sufficient. I would argue that Baltimore is inefficiently protecting Baltimoreans from extreme heat events. These documents—the multi-hazard mitigation plan, the climate action plan, and sustainability plan—should be combined into a single family of integrated documents during the rewrite process.

During the rewrite process, my matrix (see table 10 on page 73) provides a Baltimore planner with the ability to understand where the City's extreme heat event planning efforts are short of current hazard planning scholarship. The literature review—Chapter 2: Requisite Extreme Heat Event Knowledge for Planners—serves as a brief primer on improving extreme heat event mitigation efforts without requiring the planner to dedicate an inordinate amount of time researching and reading additional articles, books, and studies.

Chapter 4 - Conclusion

Extreme heat events will continue to pose a threat to populated areas. Climate change is aggravating the risk posed by extreme heat events. The development of multi-hazard mitigation plans is a complex task involving a great deal of information and data that may or may not be readily available to planning professionals. However, information on individual hazards is readily available, often through the academic work of other fields, specifically emergency management, public health, and climatology. The volume of information on a single hazard can overwhelm a researcher, especially when hazard mitigation likely makes up little or no part of a planner's formal education background.

This paper seeks to provide planners with an introduction to background knowledge on extreme heat events. While the knowledge is relatively base level, this paper can serve as guidance while developing the extreme heat event portion of any multi-hazard mitigation plan. The flow of the literature review can serve as a workflow template for the research and work necessary to develop a plan that protects the residents and enhances the life of a city during the hottest days and weeks of the year. Planners must define extreme heat events in their city based upon the city's history of extreme heat events. Knowing how climate change and the urban heat island effect modify extreme heat events shall provide guidance on the urgency of a multi-pronged mitigation effort. Identifying the socially vulnerable residents of the city will increase the equity of mitigation efforts while efficiently prioritizing the people and areas who are most likely unable to cope and recover from extreme heat events.

Appendix A – Figure Citations

Figure 1: Flowchart of Literature Review, page

Asgarali-Hoffman, Andrew. (Digital Designer). (2017, August). *Flowchart of Literature Review Topics* [digital image].

Figure 2: National Weather Service Heat Index Chart, page

National Weather Service (publisher). (n.d.). *Heat Index* [digital image]. Retrieved from http://www.wrh.noaa.gov/psr/general/safety/heat/heatindex.png

Figure 3: An exhausted emergency responder rests against a car, page

Greer, Paul (Photographer). (1995, July 17). *Overwhelming task* [digital image]. Retrieved from http://www.trbimg.com/img-55a6af7e/turbine/chi-95heatcop20120706072405/450/253x450

Figure 4: Chicago paramedics respond to a heat-related emergency involving an elderly victim, page

Kale, Walter (Photographer). (1995, August 13). *Elderly assist* [digital image]. Retrieved from http://www.trbimg.com/img-4ff6f59e/turbine/chi-95heatwoman20120706072538/750/750x422

Figure 5: Cook County morgue workers walk between rows of refrigerated trucks outside the morgue, page

Fisher, Mike (Photographer). (1995, July). *Untitled* [digital image]. Retrieved from http://media.npr.org/assets/img/2012/09/10/chicagoheatwave_wide-c527a9d6ea9bff31cf0622cb9260a5965ce15e87-s700-c85.jpg

Figure 6: The Globe's Ten Hottest Years on Record, since 1880, page

Climate Central (Publisher). (2016, July 20). *Ten Hottest Years* [digital image]. Retrieved from http://www.climatecentral.org/gallery/graphics/the-10-hottest-years-on-record

Figure 7: Rate of Temperature Change in the United States, 1901-2008, page

Centers for Disease Control and Prevention (Publisher). (n.d.). *Rate of Temperature Change in the United States, 1901-2008* [digital image]. Retrieved from https://www.cdc.gov/climateandhealth/pubs/climatechangeandextremeheatevents.pdf

Figure 8: Projected increase in number of days per extreme heat event of the longest event each year under the most likely future global greenhouse gas emissions scenario, page

Centers for Disease Control and Prevention (Publisher). (n.d.). *Projected increase in number of days per extreme heat event of the longest event each year under the most likely future global greenhouse gas emissions scenario* [digital image]. Retrieved from https://www.cdc.gov/climateandhealth/pubs/climatechangeandextremeheatevents.pdf

Figure 9: Mapped comparison of cities' projected future summer high temperatures to a city’s current summer high temperatures under unabated climate change, page

Climate Central (Publisher). (2014, August 1). *1001 Blistering Future Summers* [digital images]. Retrieved from http://www.climatecentral.org/news/summer-temperatures-co2-emissions-1001-cities-16583

Figure 10: Heat kink on a Washington Metro Green Line track, page

WMATA (Photographer). (2012, July 6). *Untitled* [digital image]. Retrieved from https://www.washingtonpost.com/blogs/dr-gridlock/post/metro-heat-kink-in-rail-likely-caused-derailment/2012/07/07/gJQAKJTEUW_blog.html

Figure 11: North Carolina work crew repairs highway buckled by extreme heat, page

Long, Travis (Photographer). (2012, June 29). *Untitled* [digital image]. Retrieved from http://www.nytimes.com/2012/07/26/us/rise-in-weather-extremes-threatens-infrastructure.html

Figure 12: Map of Cutter's Social Vulnerability Index using county-level Census data, page

Hazards & Vulnerability Research Institute (Publisher). (n.d.). *Social Vulnerability Index 2010-2014* [digital image]. Retrieved from https://artsandsciences.sc.edu/geog/hvri/sovi®-0

Figure 13: Map of Rhode Island's social vulnerability using the CDC's Social Vulnerability Index mapping tool, page

Agency for Toxic Substances & Disease Registry (Publisher). (2014). *Social Vulnerability Index (SVI) Mapping Dashboard* [digital image]. Retrieved from https://svi.cdc.gov/map.aspx

Figure 14: Example of an easy to understand graphic explaining the difference between heat exhaustion and heat stroke, page

National Weather Service & Sacramento Office of Emergency Services (Publishers). (n.d.). *Heat Exhaustion or Heat Stroke* [digital image]. Retrieved from http://www.nws.noaa.gov/om/heat/heat-illness.shtml

Figure 15: Centers for Disease Control and Prevention extreme heat event informational poster geared towards the public, page

Centers for Disease Control and Prevention (Publisher). (2013). *Beat the Heat* [digital image]. Retrieved from https://www.cdc.gov/phpr/infographics/beattheheat.htm

Figure 16: Compressed Literature Review Workflow for Case Study Discussion

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